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Stink Bug (Hemiptera: Heteroptera: Pentatomidae) Ecology in Nebraska Agroecosystems

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STINK BUG (HEMIPTERA: HETEROPTERA: PENTATOMIDAE) ECOLOGY IN NEBRASKA AGROECOSYSTEMS

by

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STINK BUG (HEMIPTERA: HETEROPTERA: PENTATOMIDAE) ECOLOGY IN NEBRASKA AGROECOSYSTEMS

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Advisors: Thomas Hunt and Robert Wright

Stink bugs (Hemiptera: Heteroptera: Pentatomidae) have gained considerable attention in Nebraska in the last decade due to increasing densities of native stink bug and spread of invasive species in the Midwest. Little is known about stink bug dynamics in Nebraska cropping systems. Based on data from a recent field survey, specimens at the University of Nebraska State Museum and the diagnostic lab of the Entomology Department at the University of Nebraska Lincoln, as well as published literature, we present a checklist of 72 species and subspecies of Pentatomidae (55 Pentatominae, 13 Asopinae, 3 Podopinae and 1 Edessinae) that occur in the state of Nebraska. Twenty five are new state records. Survey of corn and soybean fields in 2017, 2018 and 2019 show a stink bug complex consisting of 10 phytophagous and one predatory species, *Podisus maculiventris* (Say). The most abundant species is the onespotted stink bug, *Euschistus variolarius* Palisot de Beauvois, which made up approximately 83% and 67% of total adult samples collected in corn and soybean, respectively. Data suggest that Nebraska stink bug population are bivoltine and within field distribution show no edge effect. Investigation of the parasitoid complex infesting stink bugs in Nebraska yielded two adult parasitoids *Euthera tentatrix* Loew and *Cylindromyia fumipennis* (Bigot) (Diptera: Tachinidae), and one egg parasitoids

Telenomus podisi Ashmead (Hymenoptera: Platygastridae). Overall parasitism rate was ~1.5% by Dipterans, while mean parasitism was up to 90% by the egg parasitoid. The effect of feeding damage on field corn artificially infested with adult *Euschistus variolarius* (Palisot de Beauvois) had kernel damage ranging from 0.22% to 18% depending on pest density. Understanding the different aspects of stink bug ecology will provide answers to some of the elements of integrated pest management (IPM) necessary for making informed management decisions that will benefit growers in Nebraska and by extension, the Midwest. This is in the hope that losses due to stink bug damage will be reduced and ultimately, lead to increased profitability for growers.

DEDICATION

TO THE MEMORIES OF

Lucas Fanowo Ademokoya (01/01/1943 – 11/20/2010)

Elizabeth Aladesola Ademokoya (née Faseesin) (07/10/1950 – 03/06/2013)

Oluwatomisin David Ademokoya (02/23/1980 – 11/16/2013)

Adegoke Daniel Eyeowa (01/07/1983 – 12/04/2020)

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Stink Bug Diversity, Distribution, and Abundance in North America

Stink bugs (Hemiptera: Heteroptera: Pentatomidae) are true bugs that have members that are phytophagous or predaceous. There are approximately 5000 described species in 900 genera and 10 subfamilies worldwide (Schuh and Slater 1995). Five subfamilies of stink bug occur in North America. These are Discocephalinae, Edessinae, Pentatominae, Podopinae and Asopinae. The first four have members that are phytophagous, while Asopinae are predaceous. Among the phytophagous stink bugs, the subfamily Pentatominae contains approximately 180 species and subspecies in North America (Froeschner 1988, Schuh and Slater 1995), some of which are of major economic importance. Stink bug species that are currently pests of concern in agricultural production in the United States include *Chinavia hilaris* syn = *Acrosternum hilare* (Say) (green stink bug), *Nezara viridula* (L.) (southern green stink bug), *Euschistus servus* (Say) (brown stink bug), *Euschistus variolarius* (Palisot de Beauvois) (onespotted stink bug), *Euschistus tristigmus* (Say) (Dusky stink bug), *Oebalus pugnax* (F.) (rice stink bug), *Murgantia histrionica* (Hahn) (Harlequin bug), *Thyanta custator* McAtee (redshouldered stink bug), *Chlorochroa ligata* (Say) (Conchuela bug), *Cosmopepla lintneriana* (Kirkaldy) (twice-stabbed stink bug), *Piezodorus guildinii* (Westwood) (redbanded stink bug) and *Halyomorpha halys* (Stål) (brown marmorated stink bug) (McPherson and McPherson 2000, Hoebeke and Carter 2003, Tindall and Fothergill 2011, Tindall et al. 2012, Temple et al. 2013a, Basnet et al. 2014, Koch 2014, Koch and Pahs 2014, 2015, Leskey et al. 2012a, Michel et al. 2015, Koch et al. 2017).

Stink bug diversity ranges from 40 – 60 species per region in North America (McPherson 1982, Maw et al. 2000, Rider 2012, Packauskas 2012, Sites et al. 2012, Swanson 2012, Paiero et al. 2013, Koch et al. 2014). For example, in the Midwestern states of North Dakota, Michigan, Minnesota, and Missouri, the stink bug population comprises 45, 48, 51, and 56 species, respectively (Rider 2012, Sites et al. 2012, Swanson 2012, Koch et al. 2014). In Canada, 50-53 species are likely to be encountered (Maw et al. 2000, Paiero et al. 2013). The distribution, species composition, prevalence, and relative abundance of stink bug differ by region, crop type, and temporal dispositions (Temple et al. 2013a, Basnet et al. 2014, Koch and Pahs 2014, Vyavhare et al. 2014). While some species are widely distributed, others have limited distribution. For example, *Chinavia hilaris* occurs throughout most of the United States (McPherson 1982, Drees and Rice 1990, McPherson et al. 1993, 1994, Jones et al. 1996, Baur et al. 2000, Aldrich et al. 2009) and southern Canada (Javahery 1990, Paiero et al. 2013). However, its superficial look-alike, *Nezara viridula*, is limited to the warmer southeastern United States and California (Hoffman et al. 1987, McPherson et al. 1994), with one adventive encounter in Canada (Maw et al. 2000). The most predominant species in field crops like soybean *Glycine max* (L.) Merrill and corn *Zea mays* (L.) in the southeastern United States is *N. viridula* (Drees and Rice 1990, McPherson et al. 1993, 1994, Baur et al. 2000, Gore et al. 2006, Herbert and Toews 2012), whereas *E. variolarius* is the most abundant in the Midwest for the same crops (Koch and Pahs 2014, Koch and Rich 2015, Pezzini et al. 2019). Species composition and relative abundance of the stink bug fauna in a particular geographic area may shift over time (E.g., Baur et al. 2000 vs. Temple et al. 2013a, Drees and Rice 1990 vs. Vyavhare et al. 2014, Leskey and Hogmire 2005 vs. Leskey et al. 2012a), especially in the face of a changing climate and spread of invasive species. In the last decade, studies have shown that *P. guildinii*, an invasive species, is gradually taking over southern soybean, and has now become the most prevalent species in Louisiana and Texas, as opposed to *N. viridula* (Baur et al. 2000, Temple et al. 2013a, Vyavhare et al. 2014). Additionally, another invasive species, *H. halys*, that was introduced to Pennsylvania in 1996 (Hoebeke and Carter 2003), is now established in the southeastern United States and is the predominant stink bug species in mid-Atlantic orchards (Nielsen and Hamilton 2009, Leskey et al. 2012a). This is contrary to Leskey and Hogmire (2005) where *E. servus* was the most abundant species. In recent years, there have been several reports of both *H. halys* and *P. guildinii* gradually spreading towards the Midwest (Tindall and Fothergill 2011, Leskey et al. 2012a, Michel et al. 2015, Rice et al. 2014).

1.2 Biology, Behavior, Population and Seasonal Dynamics of Stink Bug in North America

When temperature drops in fall, adult stink bugs undergo reproductive diapause (Ali and Ewiess 1977, Borges et al. 1998, Saulish and Musolin 2012) and start to search for overwintering sites in structures such as tree trunks, underneath leaf litter and debris (Jones and Sullivan 1981, Saulish and Musolin 2012, Rice et al. 2014). Some species like *H. halys* overwinter in homes where they constitute nuisance (Leskey et al. 2012a, Rice et al. 2014). Other species, like *N. viridula* and *M. histrionica*, are known to be active all year long during mild winters (Singh 1973, Todd 1989). When temperature rises in spring, adults emerge from overwintering sites and move to nearby plants. This could be early planted crops, or mostly, wild hosts such as shrubs, trees, and grasses where they feed, mate, and lay eggs (McPherson 1982). Populations build up on these initial host plants, and they often move into cultivated crops later in the season. As the season progresses, they move from senescing crops to preferably, other crops in reproductive growth stages (Panizzi 1997, Pilkay et al. 2015).

Females lay barrel-shaped eggs in clusters on plant tissues, usually on leaves (McPherson 1982, Panizzi et al. 2000). These eggs hatch into nymphs which undergo five instars to become adults (McPherson 1982, Todd 1989). First instar nymphs remain in a cluster and generally do not feed until the first molt, after which they gradually start to disperse (McPherson 1982, Todd 1989, McPherson and McPherson 2000). Depending on environmental conditions, the complete life cycle from egg to adult takes about 23 – 60 days (Chanthy et al. 2015, Harris and Todd 1980a). For example, at 25 – 28^{o}C, 55 – 65% RH, and 14:10 LD photoperiod, the mean developmental period for *N. viridula* is 36.7 days (Harris and Todd 1980a). Stink bugs undergo many generations per year depending on photoperiod (Wilde 1969). In North America, the number of generations per year range from one (univoltine) in the north to five (multivoltine) in the extreme south (Javahery 1990, Kamminga et al. 2009, McPherson and McPherson 2000). In the Midwest, the number of generations per year is usually one or two (McPherson 1982).

1.3 Pest Status and Economic Importance

Phytophagous members of the family Pentatomidae are associated with several wild and cultivated host plants (Kiritani et al. 1965, McPherson 1982, Clarke and Walter 1993, Panizzi and Slansky 1985, Panizzi 1997, Rice et al. 2014). Uncultivated plants play a significant role in stink bug ecology (Jones and Sullivan 1982, Clarke and Walter 1993, Panizzi 1997). They serve as alternative food and reproductive hosts, especially during spring before cultivated crops start to develop (Panizzi 1997). Wild hosts also serve as harborage for pest build-up before dispersal into cultivated crops (Douglas 1939, Jones and Sullivan 1982, Panizzi 1989, 1992, Panizzi and Saraiva 1993, Clarke and Walter 1993).

Stink bugs are major pests of economically important crops including soybean (Todd and Herzog 1980, Turnipseed and Kogan 1976, Bundy and McPherson 2000, McPherson and McPherson 2000, Herbert and Toews 2012, Temple et al 2013), cotton *Gossypium hirsutum* (L.) (Bundy and McPherson 2000, Herbert and Toews 2012), cereals like rice and corn (Foster et al. 1989, Herbert and Toews 2012, Koch et al. 2016), and tree crops (Leskey et al. 2012a). They are sap feeders and are generally considered to be polyphagous. Some species are oligophagous, showing preference to certain plant taxa, e.g., *N. viridula* prefers legumes and Brassicaceae. Adult and nymphs suck phloem sap from multiple plant parts, including stems, petioles, leaves, flowers, fruits, and seeds. Their feeding activities cause loss of turgor, deformation or abortion of seed and fruiting bodies, delayed plant maturation, dimpling of the fruit's surface, and decay. In most cases, signs of stink bug damage make fruits unsuitable for sale (McPherson et al. 1979, McPherson and McPherson 2000, Musser and Catchot 2008).

In addition to the above, punctures left by stink bug feeding can predispose plants to diseases and rot (Daugherty and Foster 1966, Daugherty 1967, Medrano et al. 2009). Some species of stink bugs are known to transmit yeast-spot disease in plants, which results in a condition known as stigmatomycosis, “a characteristic injury resulting from inoculation of plant tissue by fungi through the feeding action of piercing-sucking insects” (Ashby and Nowell 1926). Nowell (1917) associated yeast infection in cotton balls with insect feeding punctures. Yeast spot disease of soybean is caused by *Eremothecium coryli* (Kurtsman) syn = *Nematospora coryli* Peglion (Preston and Ray 1943, Lehman 1943) and has been shown to be transmitted by *C. hilaris* (Daugherty 1967). Other stink bug species that can act as potential vectors of *E. coryli* include *T. custator*, *E. servus*, *E. tristigmus*, *E. variolarius,* and *E. euschistoides* (Vollenhoven) (Daugherty 1967). Initially thought to be mechanically transmitted, Daugherty (1967) showed that *E. coryli* transmission is obligately dependent on stink bugs. *Eremothecium coryli* has been cultured from the body surface (Leach and Cluco 1943), head (Daugherty 1967), stylet, salivary gland, hindgut (Foster and Daugherty 1969), and feces (Clark and Wilde 1970) of stink bugs, confirming that adult stink bugs can retain the pathogen and that viable pathogenic pores pass through the alimentary canal. However, nymphs lose their vector capacity upon molting and need to reacquire the pathogen as adults (Clark and Wilde 1970). More recently, *Eremothecium ashbyi* (Guilliermond ex Routien) Batra, another causative organism of yeast-spot disease, was isolated from soybean in Japan (Kimura et al. 2008). Other pathogens that are transmitted by stink bugs include, *Pantoea agglomerans* (Ewing & Fife) = *Enterobacter agglomerans*, an opportunistic bacteria that causes green cotton bolls resulting in a disease known as South Carolina boll rot (Medrano et al. 2007, Medrano et al. 2009, Esquivel et al. 2010), *Botryosphaeria dothidae*, a fungal pathogen of pistachios (Daane et al. 2000), and Phytoplasma, an obligate bacteria that causes delayed maturity in soybean (Boethel et al. 2000).

In the United States, losses due to stink bug damage and control are valued at millions of dollars every year. For instance, losses in apple orchards attributed to brown marmorated stink bug, *H. halys* in the mid-Atlantic region in 2010 were estimated at $37 million (United States Apple Association 2010). Likewise, losses in cotton were estimated at $31 million in 2008 (Williams 2009). In soybean, losses due to *Piezodorus guildinii* in Louisiana were ~$28 million (Temple et al. 2013a) and an annual control cost as high as $49/ha was reported in Mississippi and Tennessee between 2003 and 2009 (Musser and Catchot 2008, Musser et al. 2009, Musser et al. 2011). Furthermore, yield loss estimates in soybean in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee from 1977 to 1984 ranged from $18-77 million per year per state (McPherson and McPherson 2000). Annual losses in rice due to *O. pugnax* was estimated at $13 million in Texas, while in Georgia, depending on year and pest density, loss estimates between 1971 and 1998 ranged from $1-23 million for soybean and $2 – 11 million for each of corn and cotton (McPherson and McPherson 200). Most of these estimates were based on the presence of multiple stink bug species, usually *C. hilaris, N. viridula,* and *E. servus* occurring together as a complex.

Stink bugs belonging to the sub family Asopinae are predatory on other insects. Hence, they act as natural enemies of insect pests (De Clercq et al. 2002). Common examples include the spined soldier bug, *Podisus maculiventris* (Say), and the twospotted stink bug, *Perillus bioculatus* (F.). *Podisus maculiventris* is a generalist predator with a broad host range consisting mainly of larvae of Lepidoptera and Coleoptera (Fig. 1) (De Clercg 2008) while *Pe. bioculatus* is considered a specialist predator of eggs and larvae of Colorado potato beetle, *Leptinotarsa decemlineata* Say (Cloutier and Bauduin 1995). Both species are considered as a candidate for classical biological control (Jermy 1980, Manole et al. 2002, De Clercg 2008). However, there are downsides to using predatory stink bugs as biological control agents. This includes their ability to attack other beneficials, high cost of mass rearing, and low natural field populations (Cloutier and Bauduin 1995, Tipping et al. 1999). Other beneficial stink bugs can be found in genera *Alcaeorrhynchus, Brochymena*, *Parabrochymena*, *Euthyrhynchus, Stiretrus, Picromenus. Rhacognathus* and *Zicrona.*

Figure 1.1 Spined soldier bug, *Podisus maculiventris* feeding on a lepidopteran larva. Photograph by B. Ademokoya.

1.4 Overwintering and Reproductive Anatomy

The internal reproductive anatomy (spermatheca, testis and sperm) has been studied in some heteropteran families including Cyndnidae (Pluot-Sigwalt and Lis 2008), Plataspidae (Kim and Lee 1993, Golec and Hu 2015), Pyrrhochoridae (Socha 2010), Coreidae (Candan 2008), and Pentatomidae (Pendergrast 1957, Ahmad and Abbasi 1971, Ahmad and Moizuddin 1975, Kim and Lee 1993, Ozyurt et al. 2013, Candan et al. 2009). Specifically, among the pentatomids, the species that have been studied include, *P. maculiventris* (Legaspi et al. 1994), *Dolycoris baccarum* (L.) (Candan et al. 2009, Ozyurt et al. 2013), *Graphosoma lineatum* (L.) (Ozyurt et al. 2013), *Eurydema* spp. Laporte de Castelnau (Candan et al. 2014), and *Pe. bioculatus* (Adams 2001), among others. McPherson and Ahmad (2012) did a comparative study of the external male genitalia of five *Euschistus* species found in the midwestern U.S.

Copulation prior to overwintering is common in insects that overwinter as adults (Denlinger 1985, Tauber et al. 1986). This behavior has been observed in Hemipterans, such as *Orius* spp. (Kobayashi and Osakabe 2008), and various Nabidae (Kott et al. 2000, Roth and Reinhardt 2003). Also, sperm storage has been documented in several Hemipteran families (Koshiyama et al. 1996, 1997a, 1997b, Kott et al. 2000, Kobayashi and Osakabe 2008). However, this has only been investigated in a few species of stinkbugs like *Nezara viridula* and *Menida scotti* (Puton) (Kiritani et al. 1966, Koshiyama et al. 1994, 1997a, 1997b, Jones and Sullivan 1981). Little is known about sperm storage in overwintering pentatomids in the midwestern United States

1.5 Spatial Pattern

Stink bugs, like other mobile polyphagous organisms, are not evenly distributed in nature. This could be attributed to cultivated plant species occurring in heterogenous patches within a large geographic area, seasonality of crops, and stink bug egg-laying behavior. Since first instar nymphs are gregarious in nature and do not disperse (Kiritani et al. 1965, McPherson 1982, Panizzi et al. 2000), this tends to generate a clumped distribution pattern at this stage. Also, adult stink bugs are very active, and as the season progresses, they move from crop to crop (Panizzi 1997). This movement, in relation to the optimal foraging theory proposed by Stephens and Krebs (1983), could be the influence of one or a combination of the following factors: developmental stage of the host plant (Smith et al. 2009), host suitability (Jones and Sullivan 1982, Velasco and Walter 1992, Funayama 1994), host preference (Siebert et al. 2005), proximity (Panizzi 1997), and pheromone signals (Harris and Todd 1980b). The resulting directional and non-random movement produces an uneven dispersal of stink bugs in the field. Studies have demonstrated that stink bug species show edge effect, that is, they are likely to be more concentrated along field borders compared to field interior (Tillman et al. 2009, Reay-Jones et al. 2010, Reeves et al. 2010, Venugopal et al. 2014). However, a more recent study has shown that stink bugs aggregate at the border as well as field interior at different levels depending on the species, developmental stage, and field location (Pezzini et al. 2019). Within field aggregation may also be influenced by vibrational signals (Lampson et al. 2010, Lampson et al. 2013). When the sampling scale is reduced to individual plants, stink bugs show non-random vertical distribution (Russin et al. 1987, Blinka 2008, Owens et al. 2013, Babu and

Reisig 2018a). To illustrate this, pod fill, number of shriveled seeds, feeding punctures, and weight of 100 seeds harvested from the upper and lower half of soybean plants were compared. Results showed that at early reproductive stage, stink bugs fed more on pods located in the upper half of plants before moving to the lower half (Russin et al. 1987). In another study, within-plant distribution of *E. servus* on corn showed that the concentration and location of stink bug at different growth stages were proportional, that is, at vegetative stage V4 (Fehr et al. 1971), stink bugs were more concentrated at the base of the plant whereas at the reproductive stage R3, there were more stink bugs on the corn ear (Babu and Reisig 2018b). Understanding within-field and within-plant distribution will facilitate faster and precise sampling and management.

1.6 Management Strategies

Based on the complexity of interactions between insects and the environment, and the various dynamics at play, the development of a sustainable management tactic for pest control centers around the concept of integrated pest management (IPM). IPM is an ecosystem-based strategy that uses a combination of compatible tactics such as cultural, biological, mechanical, semiochemicals, host resistance and chemical control to achieve long-term pest suppression, with minimal disruption to the environment. Conventional insecticides are used in a way that minimizes risk to humans, non-target organisms, beneficials, and the environment, and used only when monitoring indicates they are needed (Atkins 1978, Kogan 1998). Monitoring, sampling, and economic thresholds are foundational to a successful integrated pest management program. Stink bugs are often treated as a complex when making management decisions. This is because species share similar biology, feeding habits, and spatiotemporal pattern, with multiple species occupying the same ecological guild (McPherson et al. 1979, McPherson and McPherson 2000). Biological, chemical, and cultural approaches have been investigated in different cropping systems for the control of stink bugs.

1.6.1. Sampling and Treatment Thresholds

It is nearly impossible to count or measure every member of a pest population, hence, a portion of the population is collected as a true representation of the entire population. This works on the assumption that samples are random and independent. Sampling, if done properly, gives the closest estimate of the true mean of a pest population (Sokal and Rohlf 1969, Naranjo and Hutchison 1997). Thus, getting the appropriate sample size is important. Sampling for stink bug in soybean with a 39cm wide sweep net, Pezzini et al. (2019) suggested that an average sample size of 42 sets of sweeps (one set of sweep equals 25 sweeps), is optimal for estimating stink bug densities.

Efficient management requires dependable data that indicates when pest densities reach levels at which financial crop losses are greater than the cost of control. This information will help to determine the population density at which management action should be taken to prevent pests from reaching economic injury level. This point is known as the economic threshold (Stern et al. 1959). There are many studies on routine field monitoring of stink bug to determine thresholds (Drees 1983, Harper et al. 1993).

Thresholds are especially important for conventional chemical applications where economic justification and judicious use of pesticides are put into consideration (Harper et al. 1990). Threshold is a continuum between research-based economic thresholds, action thresholds and experience-based nominal thresholds (Poston et al. 1983).

Feeding injuries to plants and the resultant yield loss is caused by both adults and nymphs. Thus, thresholds for stink bug management are usually determined by the combined number of adults and nymphs per plant or square meter. Soybean grown for seed production has a recommended threshold of 5 stink bugs per 25 sweeps or 1 stink bug per 0.3 m (1 ft) of row (Kogan 1976). For soybean grown for grain, the threshold is 10 stink bugs per 25 sweeps or 3 stink bugs per 0.3 m (1 ft) of row (Kogan 1976). Thresholds vary for some regions or species. For example, the threshold for stink bug in Louisiana soybean is 9 stink bugs per 25 sweeps (Temple et al. 2013a). However, the threshold for the invasive stink bug *P. guildinii* has been reduced to 6 stink bugs per 25 sweeps or 0.6 stink bugs per 0.3 m (1 ft) due to its ability to cause more damage to soybean than other stink bug species (Baur and Baldwin 2006). In corn, thresholds vary with the developmental stage of the plant. For plants 2 ft and below, treatment is recommended when 10% or more of plants have stink bugs. During ear development and the start of pollen shed, the threshold is 1 stink bug per 4 plants or 25% of plants and 1 stink bug per 2 plants or 50% of plants from pollen shed to early dough stage (Hunt et al. 2011, 2014).

Sampling methods used in estimating stink bug density include ground cloth, transects/visual counts, beat bucket, sweep net and pheromone trapping (Bowling 1969, Mizell et al. 1996, McPherson and McPherson 2000, Leskey and Hogmire 2005, Venugopal et al. 2014). Each of these methods has its benefits and drawbacks, as some are more suitable to some crops than others. Sweep nets are simple, easy to use, have fast coverage, cost-effective, and better at collecting sparsely dispersed species (Rudd and Jensen 1977, Southwood 1978, Todd and Herzog 1980, Reay-Jones et al. 2009), but difficult to employ in soybean at late vegetative/early reproductive stage when soybean plants have attained a height of 35 inches, with a dense and intertwined canopy.

1.6.2 Chemical Control

In the past, use of broad-spectrum insecticides to control other pests in the field indirectly helped to suppress stink bug populations to levels that are economically insignificant (Greene et al. 1999, Bundy and McPherson 2000). However, the eradication of boll weevil in cotton, in addition to the widespread adoption of transgenic crops in the United States has led to a decreased use of broad-spectrum insecticides (Greene et al. 1999, Bundy and McPherson 2000). A correlation between the adoption rate of transgenic cotton and stink bug feeding damage in the southeastern United States has been observed and attributed to reduced pesticide application (Turnipseed and Greene 1996, Greene et al. 1999). Consequently, stink bug damage in crops has increased significantly in recent years.

Conventional insecticides are still the most widely used method for managing stink bugs. It involves the use of broad-spectrum insecticides, primarily pyrethroids, neonicotinoids, and organophosphates (Javahery 1990, Kamminga et al. 2009, Leskey et al. 2012a). As observed in other hemipteran pests such as the tarnished plant bug and southern chinch bug (Snodgrass 1996, Cherry and Nagata 2005), relative tolerance to pyrethroid, neonicotinoid, and organophosphate insecticides have been reported for *E. servus*, *C. hilaris*, *N. viridula,* and *E. heros* (Emfinger et al. 2001, Greene et al. 2001, Sosa-Gómez et al. 2001, Wilrich et al. 2003, Snodgrass 2005, Baur et al. 2010, Temple et al. 2013b). Equally important is the effect of these insecticides on beneficials and non-target organisms, and their tendency to trigger secondary pest outbreaks (Nielson et al. 2008, Leskey et al. 2012a). Therefore, alternative strategies such as biological control, trap cropping, and semiochemicals need to be adopted for stink bug management.

1.6.3 Semiochemicals

Semiochemicals are chemicals or mixtures of chemicals used in communication among organisms, causing a change in their behavior (Law and Reigner 1971, Nordlund and Lewis 1976). Semiochemicals such as pheromones mediate intraspecific communications, while allelochemicals, depending on their functional role as either kairomones, allomones or synomones, are used for interspecific communications (Dicke and Sabelis 1988, Vet and Dicke 1992). Many phytophagous insects use host-specific semiochemical odors (kairomones) as cues to locate their hosts. An example, the harlequin bug, *Murgantia histrionica* (Hahn), use host plant odors to find their host plants (Wallingford, 2012). Aggregation pheromones are the most used semiochemicals in stink bug management. They are exploited as lures for monitoring and detection, mass trapping, mating disruption, and attract and kill techniques (Smart et al. 2014). The aggregation pheromone of many species of stink bug has been discovered. Examples include *H. halys*

(Khrimian et al. 2014), *P. guildinii* (Borges et al. 2007), *P. hybneri* (Leal et al. 1998), brown-winged green bug, *Plauti stali* Scott (Sugie et al. 1996), and *N. viridula* (Mitchell et al. 1971).

For monitoring and mass trapping, pheromones are deployed in traps (Aldrich et al. 1991, 1993, 1995, Borges et al. 1998, Leskey and Hogmire 2005, Leskey et al. 2012b). This method is more efficient when used in conjunction with a killing agent (Leskey et al. 2012b). Host finding ability of natural enemies is also enhanced by semiochemicals. Many studies have proven that kairomones from the host plant or host pest can mediate tritrophic interactions (Vet and Dicke 1992, Dicke 1994, Tabayashi and Dicke 1996, Moraes et al. 1998, Dicke and van Loon 2000). Parasitoids and predators make use of these indirect cues for host location. Specifically, the wasp *Astata occidentalis* Cresson (Hymenoptera: Sphecidae), a specialist predator of *Thyanta pallidovirens* Stål makes use of odors from the host for host location (Millar et al. 2001). Also, female *Trichopoda pennipes* Fab. adult parasitoids are attracted to the male pheromone of *N. viridula* (Mitchell et al. 1971). Other studies, such as Boyd et al. (1996), Krupke and Brunner (2003), Moraes et al. (2005) demonstrated that many parasitoids of stink bug are attracted to pheromone components of their phytophagous host, or airspace volatile of the host plant induced by the phytophagous host. This is useful for recruiting natural enemies to infested sites (Morrison et al. 2018).

1.6.4 Biological control

Biological control is an important component of IPM that makes use of natural enemies to manage pest populations. In insect pest management it involves the use of predators, pathogens, and parasitoids. This can be achieved through three strategies: classical (importation), augmentation, and conservation. A biological control agent is a generalist if it feeds on or attacks a wide range of unrelated species across many families, whereas a specialist attacks only one species or a few closely related species. Egg parasitoids of stink bugs are Hymenopterans belonging to the families Platygastridae, Encyrtidae and Eupelmidae, while adult and nymph parasitoids are found in the family Tachinidae, belonging to the order Diptera. The genera *Telenomus* and *Trissolcus* in the family Platygastridae contain most of all stink bug egg parasitoids (Esselbaugh 1948, Yeargan 1979, Ehler 2002). See Table 1 for a list of parasitoids that attack stink bugs in the United States.

Table 1. Parasitoids associated with stink bugs in the United States (Am = *Acrosternum marginatum*, Ch = *Chinavia hilaris*, Eb = *Edesa bifida*, Eco = *Euschistus conspersus*, Ecr = *Euschistus crenator*, Ei = *Euschistus impictiventris*, Es = *Euschistus servus,* Ev = *Euschistus variolarius,* Eg = *Eysacoris guttiger,* Eu = *Euschistus* spp., Hh = *Halyomorpha halys*, Nv = *Nezara viridula, Pc = Plautia crossota*, Ph = *Piezodorus hybneri*, Pm* = *Podisus maculiventris*, Pb* = *Perillus bioculatus*, Tc = *Thyanta custator*, Tp = *Thyanta pallidovirens*)

Parasitoid	Host species	Family	References
Hymenoptera			
Telenomus cristatus Johnson	Ch	Platygastridae	Orr et al. 1986
Telenomus calvus Johnson	Pm	Platygastridae	Orr et al. 1986
Telenomus podisi Ashmead	Ch, Es, Ei, Ev, Hh, Nv, Pm, Eco, Tp	Platygastridae	Yeargan 1979, Orr et al. 1986, Ehler 2002, Krupke and Brunner 2003, Tillman 2010, 2011a, 2011b, 2016, Tillman et al. 2020, Peterson et al. 2021
Telenomus perplexus	Ev	Platygastridae	Krombein et al. 1979
Telenomus thyantae Ashmead	Es, Nv	Platygastridae	Tillman 2010, 2011a, 2011b
Trissolcus basalis (Wollaston)	Ch, Eco, Es, Hh, Nv, Pm, Tc, Tp	Platygastridae	Orr et al. 1986, Jones et al. 1996, Ehler 2002, Tillman 2010, 2011b, 2016, Balusu et al. 2019a, Tillman et al. 2020
Trissolcus brochymenae (Ashmead)	Es, Hh, Nv	Platygastridae	Tillman 2010, 2016, Tillman et al. 2020

Trissolcus edessae Fouts	Ch, Eb, Es, Hh, Pm	Platygastridae	Orr et al. 1986, Tillman 2016, Tillman et al. 2020
Trissolcus euschisti (Ashmead)	Ch, Es, Hh, Nv, Pb, Pm	Platygastridae	Orr et al. 1986, Tillman 2010, Tillman et al. 2020, Peterson et al. 2021
Trissolcus solocis Johnson	Hh	Platygastridae	Balusu et al. 2019b, Tillman et al. 2020
Trissolcus utahensis (Ashmead)	Eco, Ei	Platygastridae	Krombein et al 1979, Krupke and Brunner 2003
Trissolcus japonicus (Ashmead)	Hh, Nv	Platygastridae	Talamas et al. 2015, Peterson et al. 2021
Gryon obesum Masner	Eco, Es, Hh, Nv, Tp	Platygastridae	Ehler 2002, Tillman 2016, Tillman et al. 2020
Anastatus mirabilis (Howard)	Es, Hh	Eupelmidae	Tillman 2011b, 2016, Tillman et al. 2020
Anastatus reduvii (Walsh and Riley)	Es, Hh	Eupelmidae	Tillman 2011a, 2011b, 2016, Tillman et al. 2016, 2020.

Ooencyrtus californitus Girault	Eco, Nv, Tp	Encyrtidae	Ehler 2002
Ooencyrtus johnsoni (Howard)	Eco, Nv, Tp	Encyrtidae	Ehler 2002
Ooencyrtus spp. Ashmead	Es, Hh	Encyrtidae	Krupke and Brunner 2003, Tillman 2010, Tillman 2011b, 2016, Tillman et al. 2020
Hexacladia smithi Ashmead	Ecr	Encyrtidae	Krombein et al 1979
Diptera			
Trichopoda pennipes Fab.	Es, Ev, Hh	Tachinidae	Parish 1938, Duncan 2017, Leskey et al. 2018
Cylindromyia fumipennis (Bigot)	Ev	Tachinidae	Rings and Brooks 1958, Duncan 2017
Cylindromyia binotata (Bigot)	Ev	Tachinidae	Rings and Brooks 1958
Euthera tentatrix Loew	Ev	Tachinidae	Rings and Brooks 1958, Duncan 2017
Euclytia flava (Townsend)		Tachinidae	Duncan 2017
Gymnosoma fuliginosa Robineau-Desvoidy	Ev	Tachinidae	Parish 1934, Arnaud 1978

Gymnosoma filiola Loew	Eco	Tachinidae	Arnaud 1978, Krupke and Bruner 2003
Gymnoclytia immaculata (Macquart)	Ev	Tachinidae	Parish 1934[#]
Gymnoclytia occidua (Walker)	Ev	Tachinidae	Rings and Brooks 1958, Aldrich et al. 1991, Duncan 2017
Gymnoclytia occidentalis Townsend	Eco	Tachinidae	Arnaud 1978, Krupke and Brunner 2003

*** = predatory stink bug species**

[#] = reported as *Cistogoster immaculata* Macquart

Predators are often observed in the field feeding on a wide range of arthropods (Tillman et al. 2020). Because they are mostly generalists, evidence of predation is best determined through molecular analysis of gut content (Greenstone et al. 2014, Tillman et al. 2015, Athey et al. 2020). A few predator species such as *A. occidentalis* (Arnet 1993, Evans 1996), and *Pe. bioculatus* (Cloutier and Bauduin 1995) are considered to be relatively specialist. Common examples of predators that have been identified feeding on different life stages of stink bug include, *Centruroides vittatus* (Say) (Scorpiones: Buthidae), *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), *Nabis americoferus* Carayon (Hemiptera: Nabidae), *Oxyopes salticus* Hentz (Araneae: Salticidae), *Schistocerca americana* (Drury) (Orthoptera: Acrididae), *Melanoplus femurrubrum* (DeGeer) (Orthoptera: Acrididae), *Conocephalus fasciatus* (DeGeer) (Orthoptera:

Tettigoniidae), *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), *Orius tristicolor* (White) (Hemiptera: Anthocoridae), *Geocoris punctipes* Say (Hemiptera: Geocoridae), *Geocoris pallens* Stal (Hemiptera: Geocoridae), *Hippodamia convergens* Guérin-Méneville (Coleoptera: Coccinellidae), *Harmonia axyridis,* (Pallas) (Coleoptera: Coccinellidae), *Coccinella. Septempunctata* (L.) (Coleoptera: Coccinellidae), *Sinea diadema* (F.) (Hemiptera: Reduviidae) *Zelus renardii* Kolenati (Hemiptera: Reduviidae), *Mecaphesa asperata* (Hentz) (Araneae: Thomisidae), *Notoxus monodon* (F.) (Coleoptera: Anthicidae), *Peucetia viridans* (Hentz) (Araneae: Oxyopidae), *Solenopsis invicta* Buren (Hymenoptera: Formicidae), and *Podisus maculiventris* (Hemiptera: Pentatomidae) (Ehler 2002, Rice et al. 2014, Abram et al. 2015, Morrison et al. 2016, Athey et al. 2019, Tillman et al. 2016, 2020). Pathogens that are used for stink bug management include the enthomopathogenic fungi *Metarhizium anisopliae* (Ihara et el. 2001, 2008) and *Beauveria bassiana* (Gouli et al. 2012), as well as a microsporidian, *Nosema maddoxi* (Hajek et al. 2018, Preston et al. 2020).

Other methods of managing stink bugs involve manipulating the environment to negatively impact the densities of stink bug populations. These methods have varying degree of success. Some of the methods that have been tried includes tillage (Lema et al. 1980, Funderburk et al. 1990), sanitation (Panizzi 1997), planting date (McPherson et al. 1988, Bundy and McPherson 2000), row spacing (McPherson et al. 1988, Lam and Pedigo 1998), conservation of beneficial organisms, use of resistant varieties, and trap cropping (McPherson and Newsom 1984, Wallingford 2012).

1.7 Justification for Study

Historically, stink bugs are important pests of many economic crops, especially in the southeastern region of the United States. These crops include corn and soybean, the two most planted field crops in the United States with an annual production value of 14 and 4.4 billion bushels, respectively, and a combined market value estimated at almost $90 billion (USDA- NASS 2021). This makes the United States the largest producer and exporter of corn and soybean in the world. About 80% of this production comes from the Midwest, specifically, Illinois, Iowa, Indiana, Minnesota, and Nebraska. Corn and soybean are grown extensively in Nebraska (NDA 2021). Nationally, Nebraska ranks 3rd for corn, and 4th for soybean production (USDA- NASS 2021), making corn and soybean part of Nebraska's top five leading agricultural commodities (NDA 2021).

Populations of native stink bugs such *E. variolarius, E. servus, T. custator* and *C. hilaris* have been increasing in the Midwest (Koch and Pahs 2014, Koch et al. 2017). Also, there are reports of invasive species dispersing northwards from the southeast (Tindall and Fothergill 2011, Leskey et al. 2012a). Hence, there is need for routine sampling and monitoring of stink bug populations across all regions. In Nebraska, little is known about the species composition and seasonal abundance of the stink bug fauna. Also, there is no treatment threshold specific to Nebraska due to inadequate data, and consequently, little research-based management recommendations for stink bug control in Nebraska corn and soybean.

Furthermore, a survey of the stink bug fauna of Nebraska was last done more than a hundred years ago. About 47 members of the family Pentatomidae were reported

(Zimmer 1911, 1912). Over the years, half of these species have either been moved around in their taxonomic delineations or their names completely changed. Additionally, there are new state records from the current study that were not included in the first survey. This calls for a review of the stink bug species in Nebraska.

Overall, the objective of this dissertation is to provide a general overview of the biology, ecology, distribution, up-to-date taxonomic classification, and diversity of stink bugs in Nebraska. Also, this study will provide information on the spatial pattern, seasonal abundance, species composition, and relative abundance of stink bugs in Nebraska corn and soybean, as well as research-based threshold for stink bug in corn specific to Nebraska. Lastly, this study will highlight the parasitoid complex of stink bug that are present in Nebraska.

1.8 Dissertation Goals and Outline

The long-term goal of this study is to develop an IPM program for the management of stink bugs in corn and soybean by providing research-based recommendations to growers in Nebraska, and by extension, the Midwest. This is in the hope that losses due to stink bug damage will be reduced and ultimately, lead to increased profitability for growers.

This study has five objectives:

1) Understand the diversity, density, and relative abundance of stink bugs in the Nebraska corn-soybean agroecosystem.

2) Evaluate the seasonal occurrence and spatial distribution of stink bugs in corn and soybean.

3) Identify the parasitoids of stink bugs in Nebraska, investigate their distribution and potential as biological control agents.

4) Carry out yield loss assessment to establish treatment threshold in corn.

5) Investigate the potential of Nebraska stink bug populations as vectors of yeast pathogens

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CHAPTER 2

THE PENTATOMIDAE (HEMIPTERA: HETEROPTERA) OF NEBRASKA: AN ANNOTATED CHECKLIST AND NEW STATE RECORDS

2.1 Abstract

We present an annotated checklist of Nebraska stink bug (Hemiptera: Pentatomidae) based on a 3-year field survey, collections at the University of Nebraska State Museum and the diagnostic lab of the Entomology Department at the University of Nebraska Lincoln, as well as published literature. In total, seventy two species and subspecies of Pentatomidae (55 Pentatominae, 13 Asopinae, 3 Podopinae and 1 Edessinae) are listed as occurring in the state of Nebraska. Twenty five of these are new state records; Asopinae: *Alcaeorrhynchus grandis* (Dallas), *Perillus lunatus* Knight, *Stiretrus anchorago* (Fabricius); Edessinae: *Ascra bifida* (Say); Pentatominae: *Agonoscelis puberula* Stål, *Banasa calva* (Say), *Banasa euchlora* Stål, *Banasa sordida* (Uhler), *Brochymena cariosa* Stål, *Brochymena sulcata* Van Duzee, *Chlorochroa ligata* (Say), *Chlorochroa persimilis* Horvath, *Chlorochroa sayi* (Stål), *Dendrocoris humeralis* (Uhler), *Euschistus servus servus* (Say), *Euschistus tristigmus tristigmus* (Say), *Halyomorpha halys* (Stål), *Holcostethus macdonaldi* Rider and Rolston, *Holcostethus fulvipes* (Ruckes), *Mecidea major* Sailer, *Trichopepla grossa* Van Duzee, *Tepa vanduzeei* Rider, *Thyanta calceata* (Say), *Thyanta pallidovirens* (Stål); Podopinae: *Amaurochrous dubius* (Palisot de Beauvois). In the Midwest, Nebraska currently holds the highest record for stink bug diversity, and it is the first to report a member of the subfamily Edessinae.

2.2 Introduction

The family Pentatomidae is one of the three largest families of Heteroptera, with approximately 5000 described species in 940 genera and 10 subfamilies worldwide (Schuh and Slater 1995). Five subfamilies, Asopinae, Discocephalinae, Edessinae, Pentatominae and Podopinae, comprising more than 220 species in 64 genera occur in North America (Froeschner 1988, Hoebeke and Carter 2003, Thomas et al. 2003). Out of this, about 100 species have been reported from the Midwest (Zimmer 1912, Blatchley 1926, McPherson 1982, Rider 2012, Packauskas 2012, Sites et al. 2012, Swanson 2012, Swanson et al. 2013, Koch et al. 2014). While stink bug distribution and diversity may vary by geographical location, it is not static. For instance, the southern green stink bug *Nezara viridula* (L.), harlequin bug *Murgantia histrionica* (Hahn), *Proxys punctulatus* (Palisot) and *Euthyrhynchus floridanus* (L.) which were once limited to the Southeast (Van Duzee 1904) are now present in the Midwest (McPherson and Cuda 1974, Rider 2012, Packauskas 2012, Sites et al. 2012, Koch et al. 2014). These dynamics are influenced by climatic variables and physiological plasticity of stink bug species (Kiritani 2006, Tougou et al. 2009).

Furthermore, Pentatomidae species of Neotropical, Oriental and African origin such as the brown marmorated stink bug *Halyomorpha halys* (Stål) (Hoebeke and Carter 2003), redbanded stink bug *Piezodorus guildinii* (Westwood) (Genung et al. 1964), African cluster bug *Agonoscelis puberula* (Stål) (Thomas et al. 2003), *Bagrada hilaris* (Burmeister) (Arakelian 2008), *Oebalus ypsilongriseus* (De Geer) syn = *O. grisescens* (Sailer) (Mead 1983) and *O. insularis* (Stål) (Cherry and Nuessly 2010) are invasive in the United States, with *H. halys* and *P. guildinii* already spread from their initial range in the Southeast to the Midwest (Tindall and Fothergill 2011, Leskey et al. 2012, Michel et al. 2015, Rice et al.

2014). Provided that anthropogenic-driven factors such as climate change as well as movement of goods, plants and animals across geographical areas continue, range expansion of stink bug species at both local and intercontinental levels will continue. Rising concerns about the spread of native and exotic stink bug species in the United States necessitates the need for up-to-date documentation across all regions, for reference, management, and conservation purposes.

The stink bug fauna of North America has been extensively documented (Van Duzee 1904, Blatchley 1926, McPherson 1982, Maw et al. 2000). At the regional level, Blatchley (1926) treated the Heteroptera of eastern North America with focus on the faunas of Indiana and Florida, McPherson (1982) published a compendium of the superfamily Pentatomoidea of northeastern North America with emphasis on the fauna of Illinois, Froeschner (1988) gave a detailed distribution information and nomenclatural changes (synonyms) of species that occur in Canada and continental United States, while Paiero et al. (2013) gave a user-friendly pictorial representation of the identification keys to species known from Ontario and adjacent areas. State-wide surveys have been carried out in Nebraska (Zimmer 1912), Virginia (Hoffman 1971), North Dakota (Rider 2012), Minnesota (Koch et al. 2014), Michigan (Swanson 2012), Missouri (Sites et al. 2012), Arkansas (Barton and Lee 1981), Connecticut (O'Donnell and Schaefer 2012), New Mexico (Bundy 2012), Washington state (Zack et al. 2012) and Kansas (Packauskas 2012). Identification keys to North America stink bug species have been provided by many authors (Van Duzee 1904, Blatchley 1926, McPherson 1982, Paiero et al. 2013). Also, state-specific keys have been developed for Nebraska (Zimmer 1912), Kansas (Packauskas 2012), Michigan (Swanson 2012), North Dakota and Minnesota (Rider 2012). These publications, collectively provide sufficient information on the identification, taxonomy, distribution, and ecological interactions of the stink bug species that are likely to be encountered in the Midwest.

Unlike the other states with relatively recent studies, the Pentatomidae of Nebraska was last investigated more than a century ago. John Todd Zimmer reported 47 species of Pentatomidae as occurring in the state of Nebraska (Zimmer 1912). Over the years, 50% of these species have been moved around in their taxonomic delineations and their names changed. For instance, two of the species he reported, *Thyanta rugulosa* Uhler and *Thyanta punctiventris* Van Duzee, have been shown to be synonyms of *Tepa rugulosa* (Say) (Rider 1986). Also, *Peribalus abbreviatus* Uhler *and Peribalus limbolarius* (Stål) have been moved to the genus *Holcostethus* Fieber (McDonald 1974) while *Apateticus bracteatus* (Fitch) and *Apateticus cynicus* (Say) are now in the genus *Apoecilus* Stål (Thomas 1992). The genus *Liodermion* Kirkaldy is now treated as *Chlorochroa* Stål (Thomas 1983), *Solubea* Bergroth as *Oebalus* Stål (Sailer 1957) and *Perilloides* Schouteden as *Perillus* Stål (Van Duzee 1916). Furthermore, *Brochymena arborea* (Say) and *Hymenarcys aequalis* (Say) have been moved to new genera and are now referred to as *Parabrochymena arborea* (Say) (Larivière 1992) and *Mcphersonarcys aequalis* (Say) (Thomas 2012), respectively. Other changes include *Nezara hilaris* and *Euschistus fissilis* which are now treated as *Chinavia hilaris* (Rolston 1983) and *Euschistus servus euschistoides* (Van Duzee 1916), respectively. McPherson (1982), Froeschner (1988) and Thomas (1992) provide detailed information on rank and nomenclatural changes.

In addition to updating taxonomic changes, the increasing densities of native stink bug in the Midwest (Hunt et al. 2011, 2014, Michel et al. 2013) and continuing dispersion of exotic species across North America (Tindall et al. 2012, Tindall and Fothergill 2011, Leskey et al. 2012, Koch 2014) implies that the diversity of the stink bugs in Nebraska would have changed over the decades. Hence, the need for an updated annotated checklist of Nebraska Pentatomidae. As species move in and out of this geographic range, the current list will serve to highlight diversity shifts in subsequent surveys. This chapter provides information on the diversity, local distribution, taxonomic and nomenclatural changes of stink bug species recorded for Nebraska. In addition, an inventory of stink bug species that have been reported in the Midwest is furnished.

2.3 Materials and Methods

Field collections. We examined approximately 3500 adult stink bugs collected from agricultural and residential landscapes including corn *Zea mays* L., soybean *Glycine max* L. Merrill, wheat *Triticum aestivum* L., alfalfa *Medicago sativa* L., beans *Phaseolus vulgaris* L., various shrubs, ornamentals, and grasses in eastern and western Nebraska (Figure 2.1). These were collected between 2017 and 2021 using sweep net, visual observation, pheromone baited traps (see chapter 3 for description of these three collection methods), sticky trap, and black light trap. Blacklight trap used is omnidirectional, with a 15 watt uv light bulb (Figure 2.2).

Primary literature. Stink bug species previously reported in literature as occurring in the state of Nebraska (Uhler 1876, Zimmer 1911 and 1912, Wheeler 2015 and 2018) were included. Most of the specimens reported by J. T. Zimmer were found in the University of Nebraska State Museum, while A. G. Wheeler Jr. deposited specimens in the U.S. National Museum of Natural History, Smithsonian Institution, Washington D.C.

Curated specimens. Pentatomidae specimens held in the University of Nebraska State Museum (UNSM) were examined. This collection contains a significant number of specimens from all regions of Nebraska, with some specimens dating as far back as 1884. Additionally, teaching collection specimens in the diagnostic lab of the department of Entomology at the University of Nebraska-Lincoln (UNL-ENTO) were also included in this study. Private collections from faculty and students were also included. Altogether, over 6000 curated specimens were examined. Specimens not designated as either UNSM or UNL-ENTO are from recent field surveys. Where no specimens are available, species were listed based on the authority of previously published literature.

Figure 2.1. Map of Nebraska counties (shaded) showing locations for stink bug samples collected between 2017 and 2021 that were included as part of the Nebraska Pentatomidae checklist.

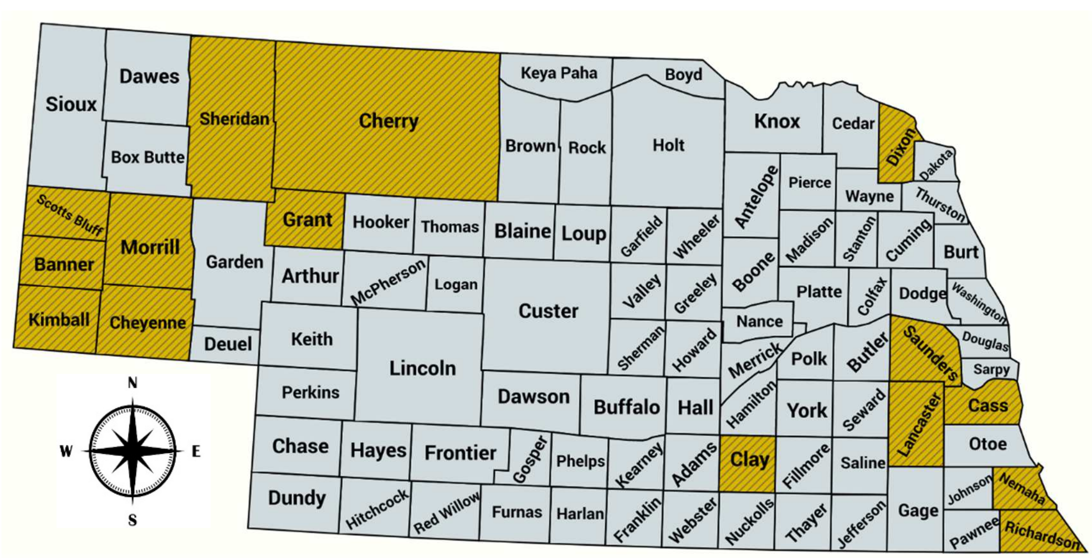
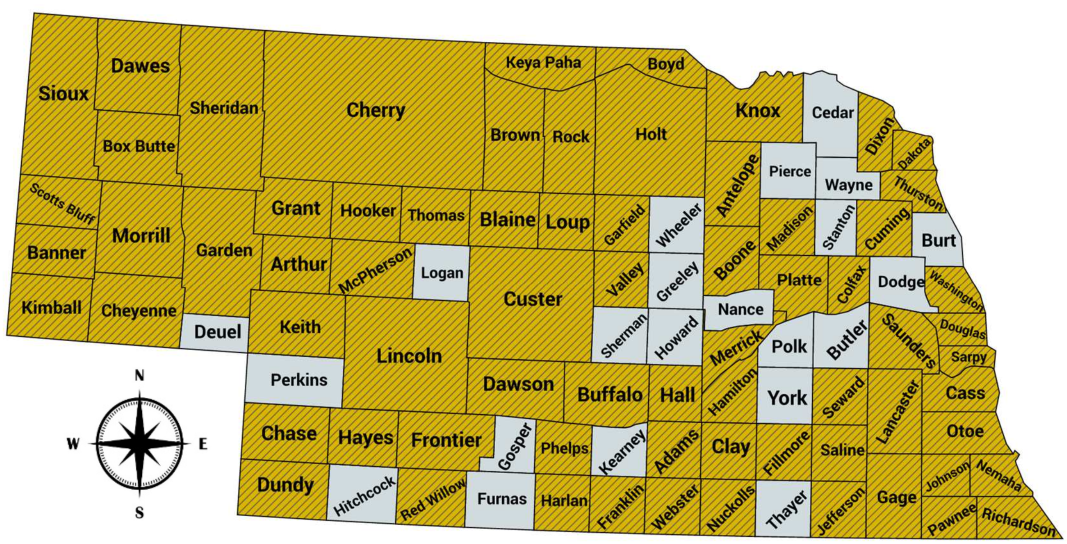


Figure 2.2. Black light trap set up at Eastern Nebraska Research and Extension Center (ENREC), Saunders Co., NE. Photograph by E. Knoell.

Identification. Diagnostic keys used for identification and verification were mostly based on the work of McPherson (1982), Rider (2012), and Paiero et al. (2013), with supplemental information from Van Duzee (1904), Zimmer (1912), Barber and Sailer (1953), Rider (1986), Larivière (1992) and Thomas (1992). A large portion of the specimens in the museum holdings have been authoritatively determined. However, due to the extensive time gap and possible rank changes, the identities of all specimens were verified for accuracy.

Some of the changes in location from Zimmer (1912) include Child's Point in Sarpy County which has been renamed Fontenelle Forest. Also, specimens collected from War Bonnet Canyon currently in Dawes County were previously assigned to Sioux County and lastly, Brady Island in Lincoln County is now called Brady. Also worthy of mention is that Dismal River runs through two counties: Hooker and Grant. Because the county was not specified, specimens from this location were assigned to Hooker County for the sake of specificity. Based on all data sources, stink bug has been collected from 76% of Nebraska counties (Figure 2.3).

Figure 2.3. Map of Nebraska counties (shaded) showing the location for all stink bug specimens included in the Nebraska Pentatomidae checklist.



Tribal allocation and authorship followed in this work is based on Rider (2012), except where otherwise stated. Arrangements within and among taxonomic ranks are alphabetical for ease of access.

2.4. Results and Discussion

After examination of specimens and reconciling nomenclatural and taxonomical changes from previously published list for Nebraska Pentatomidae, we found that 72 species of Pentatomidae (55 Pentatominae, 13 Asopinae, 3 Podopinae and 1 Edessinae) occur in Nebraska. Twenty four of these species are new state records. Six of the identified species; *Amaurochrous brevitylus* Barber and Sailer, *Apateticus marginiventris* (Stål), *Chlorochroa belfragii* (Stål), *Neottiglossa trilineata* (Kirby), *Thyanta perditor* (Fab.) and *Podisus brevispinus* Philips were not represented in any of the specimens examined but were included based on the authority of previously published works (Uhler 1876, Zimmer 1911, 1912, Wheeler 2015, 2018). With 42 species from Ohio (Furth 1974, Welty et al. 2008, Chordas 2015), 45 from North Dakota (Rider 2012), 47 from Kansas (Packauskas 2012), 51 from Minnesota (Koch et al. 2014), 52 from Michigan (Swanson 2012), 56 from Illinois (McPherson 1982), and 57 from Missouri (Sites et al. 2012), Nebraska currently has the highest stink bug diversity among the midwestern states. About 80% of Nebraska counties have recorded the presence of stink bug. This probably explains the high diversity observed. However, there are over twenty species, some of which have been reported in almost all the adjacent states but not yet in Nebraska. Examples are *Euschistus politus* and *Trichopepla atricornis*. Also, despite being originally described from Nebraska, *Euschistus latimarginatus* was not recovered during the recent survey. More scouting needs to be done especially in locations where stink bugs have not been reported to account for these discrepancies.

Observations from the recent survey showed that species composition and diversity vary from eastern to western Nebraska. For instance, *Chlorochroa ligata,* and *C. sayi* were collected only from Nebraska Panhandle which is in west. These species make up a significant portion of the samples collected from this region. On the other hand, *Euschistus variolarius* made up more than 60% of all samples collected from eastern Nebraska, making it the most abundant species in this region. This contradicts the observations of Zimmer (1912), where *E. variolarius* came second in abundance after *H. limbolarius* in eastern Nebraska. This kind of species composition/population shift is not uncommon.

The *Euschstus tristigmus* complex was divided into 3 subspecies, *E. tristigmus luridus, E. tristigmus tristigmus* and *E. tristigmus pyrrhocerus* until it was resolved by McPherson (1974) who determined that the last two are synonyms. *Euschistus t. luridus* is of northern distribution and has rounded humeri while *E. t. tristigmus* is more southern in distribution and has pointed humeral angles (McPherson 1974). Zimmer (1912) did not divide the *E. tristigmus* specimens he examined into subspecies. However, an examination of specimens of *E. tristigmus* in the museum holdings collected and/or determined by Zimmer showed that both subspecies were represented.

Additional observations include a handful of brown marmorated sink bugs, *Halyomorpha halys*, collected mostly through sticky traps. *Halyomorpha halys* is currently not a pest of agricultural concern in Nebraska. However, as population density increase in coming years, movement into cultivated landscapes is expected. A single specimen of *Ascra bifida* and *Alcaeorrhynchus grandis* were also reported. Only two species of *Ascra* and *Alcaeorrhynchus* occur in North America. McPherson (1982) gave the distribution of *Ascra* (= Eddessa) *bifida* as “Maryland south to Florida, then west to Texas, and south through Mexico and Central America to Columbia northern Brazil”. These two species occur mostly in the south, thus, the single specimens found in Nebraska are at best adventitious. The closest report to Nebraska is Arkansas (Barton and Lee 1984) and Missouri (Sites et al. 2012) for *A. bifida* and *A. grandis* respectively. Another species of interest is the African cluster bug, *Agonoscelis puberula*. Originally from Africa, this species is now reported from Mexico, southern United States, the islands of Jamaica and Hispaniola (Thomas et al. 2003), and Minnesota (Koch et al. 2014). Neither McPherson (1982) nor Froeschner (1988) listed this species for obvious reasons. There is a single female specimen of *Cosmopepla uhleri* Montandon in the museum holdings. Froeschner (1988) noted that this species was erroneously reported for Nebraska, in place of Nevada. However, this specimen collected from Sioux County is confirmation that this species occurs in Nebraska.

Aside the species mentioned above, other species that are less frequently encountered in the Midwest include *Neottiglossa trilineata, Antheminia remota, Coenus inermis, Cosmopepla intergressa, Tepa brevis*, *Piezorous guildinii*, *N. viridula*, *Conquistator mucronatus, Tylospilus acutissimus* (Stål) and *Euthyrhynchus floridanus*. Most of these less frequently encountered species were reported from Missouri. On the other hand, the following species have been reported in almost all the Midwest and adjacent states; *Perillus bioculatus, Podisus maculiventris*, *Euschistus servus servus*, *Chinavia hilaris* and *Murgantia histrionica* (See Table 2.1).

Some specimens do not perfectly key with the diagnostic keys. For instance, absence of the zig-zag abdominal pattern is one of the characteristics that distinguishes *H. limbolarius* from other members of the genus that occur in the Midwest. However, over a dozen out of the specimens of *H. limbolarius* examined have varying gradient of abdominal patterns. Also, a single specimen of *Holcostethus* that was collected from Saunders County combined the abdominal ziz-zag pattern of *H. fulvipes* with the continuous juga apices of

H. abbreviatus. This generates the problem of where precisely to assign this specimen. We provide three potential explanations to these observations. The first is the possibility of a hybrid population like what is observed in *Euschistus s. servus and E. s. euschitoides* intergrade. However, *H. fulvipes* and *H. abbreviatus* are two different species and their ability to procreate together is questionable. The second explanation is the overlap of characteristics accounting for the observed intraspecific variations within the population. This aligns with Rider's sentiment about the inaccuracy of using juga variances as a determining characteristic for members of this genus that occur in the New World (Rider 2012). The third possible explanation is that this specimen is a different species entirely. Zimmer (1912) stated "In some of the specimens, the pale margin is scalloped, and in one, I have, the dark coloration extends entirely across the margin making a maculation very similar to that in *P. abbreviatus* (Uhler). The shape of the head and scutellum, however, furnish sufficient characters to serve as distinguishing features of the two species." This observation probably suggests that this specimen is *H. fulvipes.*

The latest catalogue of Heteroptera in North America is Froeschner (1988). This catalogue contains 222 species in 60 genera. Between then and now, exotic species like *H. halys* and *A. puberula* have been added to the North America fauna. In addition to this, the catalogue omitted *T. grossa*, which was probably an oversight. This means the number of described species has increased. In the face of changing climate and global warming, stink bug species are expected to expand their range. Therefore, routine sampling and scouting should be done across the continent to provide up to date information on the stink bug diversity, for management and conservation purposes.

FAMILY PENTATOMIDAE Leach, 1815

Pentatomidae is the largest family in the superfamily Pentatomoidea. Members of this family have 5-segmented antennae, from which they got their name. They range in size from 4 to 25 mm. Body is usually ovoid with some elongate species found in the genus *Mecidea* and *Oebalus*. They have large triangular scutellum which could be U-shaped as seen in species of *Amaurochrous* and *Stiretrus*, where it covers most of the abdomen. Other families of Pentatomoidae such as Acanthosomatidae, Cynidae and Scutelleridae also have triangular and U-shaped scutellum. However, in Pentatomidae, tarsi are 3-segmented, the scutellum never completely covers the abdomen, and tibia lack spines. Sexes can be separated by the presence of overlapping sclerites and a convex genital plate covering the external genitalia in females and males, respectively (Blatchley 1926, Froeschner 1988, Schuh and Slater 1995, Paiero 2013). Of the five subfamilies that occur in North America, the subfamilies Discocephalinae and Edessinae are known to occur in the Southeastern United States. However, in addition to Asopinae, Podopinae and Pentatominae, we report a member of Edessinae as occurring in the state of Nebraska.

SUBFAMILY ASOPINAE Spinola, 1850

This group of stink bug contain members that are predatory, which makes them to be considered beneficial due to their ability to serve as biological control agents. They can be distinguished from their phytophagous counterparts by the possession of a thicker rostrum and a free first segment of rostrum which does not fit into the bucculae. Although some authors treat the tribe as Asopini, there is no generally accepted tribal arrangement for this subfamily. Thomas (1992) reported 110 species in 26 genera occurring in the New World and provided a comprehensive key to identifying these species. In North America, there are 31 described species in 12 genera (Thomas 1992), thirteen of these species occur in Nebraska.

Alcaeorrhynchus grandis (Dallas, 1851) [New State Record]

Synonyms: *Canthecona grandis* Dallas 1851: 92

Mutyca grandis Stål 1862: 58

Alcaeorrhynchus grandis Bergroth 1891: 235

Specimen Examined: Lancaster Co.: Lincoln, UNL East Campus Sept. 2021 B. Grappone (1♀).

Remarks: This is a large Asopinae, up to 24mm long. It is a predator of other insects, mostly lepidopteran larvae. This is a probably an adventitious find in Nebraska because only one species was collected. Its distribution in the United States include the southeastern states of Arkansas, Florida, Texas (Blatchley 1926) and recently reported as new state records in neighboring Kansas (Packauskas 2012) and Missouri (Sites et al. 2012).

Apateticus marginiventris (Stål, 1870)

Synonyms: *Podisus* (*Apateticus*) *marginiventris* Stål 1870: 49.

Podisus gillettei Uhler 1895: 12.

Apateticus marginiventris Kirkaldy 1909: 22.

Apateticus (*Apateticus*) *marginiventris* Zimmer 1912: 18.

Specimens Examined: No specimen was found in the collections, and none was recovered from the survey at the time of this investigation.

Remarks: Zimmer (1912) reported a female of this species collected at Monroe Canyon, **Sioux country** [sic], Nebraska collected on June 19, 1911, by R. W. Dawson. This uncommon species of predatory stink bug has been reported in Arizona, Colorado, New Mexico, and Nebraska (Thomas 1992). Neither Blatchley (1926) nor McPherson (1982) included this species in their reports. Its distribution range in North America include Arizona, Colorado, New Mexico, and Nebraska (Froeschner 1988).

***Apoecilus bracteatus* (Fitch, 1856)**

Synonyms: *Arma bracteata* Fitch, 1856: 332.

Podisus bracteatus Stål 1870: 54

Apateticus bracteatus varq. *crocata* Kirkaldy 1909: 22

Apateticus (*Apoecilus*) *bracteatus* Zimmer 1912: 19.

Specimens Examined: Red Willow Co.: Indianola, May, on *Oxytropis lambertii*, (1♂ UNSM). **Thomas Co.:** Halsey, June 1969 (1♂ UNSM).

Remarks: The specimen from Red Willow County is probably the same specimen examined by Zimmer (1912), “a male specimen was taken at Indianola in May.” Its distribution ranges from Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, and Quebec in Canada, and in the United States, it can be found in Idaho, Colorado, Connecticut, Massachusetts, Michigan, New York, Ohio, Pennsylvania, Utah, New Mexico, California, Nebraska, South Dakota, and Illinois (Blatchley 1926, McPherson 1982, Froeschner 1988).

***Apoecilus cynicus* (Say, 1831)**

Synonyms: *Pentatoma cynica* Say 1831: 3.

Apateticus (*Apoecilus*) *cynicus* Van Duzee 1904: 70

Apateticus (*Apoecilus*) *cynicus* Zimmer 1912: 19.

Apoecilus cynicus Thomas 1992: 27.

Specimens Examined: Cherry Co.: July 1977 (1♀ UNSM). **Gage Co.:** Barnston, Nov. 2018 R. Dodge (1♂ UNL-ENTO). **Sioux Co.:** Wood Reserve 5 mi. S. W. Ft. Robinson, Aug. 1983 R. E. white (1♀ UNSM). There are three additional specimens from Nebraska with no date and county information (1♂, 2 ♀♀ UNSM).

Remarks: Zimmer (1912) reported a female of this species from Glen, **Sioux county,** on July 1910 J. T. Zimmer. McPherson (1982) gave the distribution for this species as "Québec and New England south to Florida, and west to Montana, Colorado, Texas, and Arizona", while Stoner (1920) reported it from Iowa.

***Perillus bioculatus* (Fabricius, 1775)**

Synonyms: *Cimex bioculatus* Fabricius 1775: 715.

Perilloides bioculatus Zimmer 1912: 16.

Perillus bioculatus Knight 1952: 229.

Specimens Examined: Adams Co.: Sept. 1987 C. A Springer (1♂ UNSM); April 1983 T. England (1♂, 1♀ UNSM); Sept. 1983 S. Linot (1♂ UNSM); Sept. 1983 S. Carter (1♂ UNSM); Sept. 1981 M. Davis (1♂ UNSM); Dec. 1987 E. E. Youna (1♂ UNSM); Sept. 1989 M. Tharp (1♂ UNSM). **Blaine Co.:** Purdum, April 1953 (1♂ UNSM). **Cass Co.:** South Bend (1♂ UNSM). **Cherry Co.:** July 1977 **(**1♀ UNSM); March 1983 A. Uerline

(1♀ UNSM). **Cuming Co.:** West Point, Aug. 1887 (2♀♀ UNSM); October 1917 (1♂, 3♀♀ UNSM). **Dawson Co.:** Lexington, Nov. 1944 J. Hanson (1♀ UNSM). **Dundy Co.:** Haigler, July 1911 (1♀ UNSM), July 1912 J. T. Zimmer (1♂ UNSM); Haigler, Aug. 1909 C. H. Gable (1♂ UNSM). **Jefferson Co.:** Jan. 1989 S. P. Leonard (1♂ UNSM); Sept. 1989 A. Diaz (1♂ UNSM). **Keith Co.:** Cedar Point Biological Station, July 1984 B. C. Ratcliffe (1♀ UNSM). **Lancaster Co.:** Lincoln, July 1908 (1♀ UNSM), Aug. 1909 (1♂ UNSM), June 1911 (1♀ UNSM), March 1911 J. T. Zimmer (1♀ UNSM); Lincoln, July 1909 C. H. Gable (1♂ UNSM); Lincoln, July 1921 **(**1♀ UNSM), Aug. 1921 R. E. Weir (1♂ UNSM); Lincoln, April 1930 A. L. Roberts (1♀ UNSM); Lincoln, May 1944 (1♀ UNSM); Lincoln, Aug. 1955 D. W. S. Sutherland (2♂♂ UNSM); April 1916 **(**1♀ UNSM), June 1940 (1♀ UNSM), Aug. 1940 H. D. Tate **(**1♀ UNSM); Lincoln, Nov. 1953 O. S. Bare (1♂ UNSM); Lincoln, Oct. 1956 S. D. Carlson **(**1♀ UNSM); Lincoln, February 1957 (2♂♂ UNSM); Lincoln, Feb. 1983 B. C. Ratcliffe (1♀ UNSM); Lincoln, Oct. 1992 B. Kalisch (1♀ UNL-ENTO); Lincoln, Sept. 2002 J. N. Nuss (1♀ UNL-ENTO); Lincoln, Oct. 2003 D. Anderson (1♂ UNL-ENTO); Lincoln, Aug. 2004 C. Roberts (1♂, 1♀ UNL-ENTO); Lincoln, Sept. 2004 J. L. Mohlman (1♀ UNL-ENTO). **Merrick Co.:** Central City, J. S. Lindley (1♀ UNSM). **Platte Co.:** Columbus, **(**1♀ UNSM); Sept. 1989 S. Soulliere (3♂♂, 1♀ UNSM). **Red Willow Co.:** Indianola, May, on *Oxytropis lambertii* **(**1♀ UNSM). **Saunders Co.:** Valparaiso, March 1932 (1♂ UNSM). **Scotts Bluff Co.:** Morrill, Aug. 1930 D. B. Whelan (1♂ UNSM); Henry, Sept. 1940 R. E. Hill (1♂ UNSM); June 1948 E. G. Burcham (1♂ UNSM); July 1954 L. W. Andersen (2♂♂ UNSM). **Sioux Co.:** Glen, July 1910 J. T. Zimmer **(**2♀♀ UNSM); Mitchell, Aug. 1915 E. M. Partridge (1♀ UNSM). **Thomas Co.:**

Halsey, August 1911 (1♀ UNSM); Halsey, July 1912 J. T. Zimmer (1♀ UNSM); Halsey, July 1969 (2♂♂ UNSM).

Remarks: This predatory stink bug species has two color variations; red-orange and black-ivory. It is known to feed preferentially on all stages of the Colorado potato beetle and is considered a biological control agent for this pest (Whitcomb 1974, Tamaki and Butt 1878). Zimmer (1912) reported that he had specimens of this species from all parts of Nebraska. It has been reported in some Canada provinces and several states in the United States. For a complete distribution list of this species in North America, see McPherson (1982) and Froeschner (1988).

Perillus circumcinctus **Stål, 1862**

Synonyms: *Perillus circumcinctus* Stål 1862: 29.

Perilloides circumcinctus Zimmer 1912: 17.

Perillus circumcinctus Knight 1952: 231.

Remarks: No specimen of this species was found in the museum holdings, neither Zimmer (1912) reported it, and none was recovered during the recent survey. However, Uhler (1876) reported it from Nebraska. The distribution of this species spans across many regions of Canada and the United States (McPherson 1982, Froeschner 1988, Thomas 1992).

Perillus exaptus **(Say, 1825)**

Synonyms: *Pentatoma exapta* Say 1825: 313.

Perilloides exaptus Zimmer 1912: 16.

Perillus exaptus Knight 1952: 231.

Specimens Examined: Lancaster Co.: Lincoln, Sept. (1♂ UNSM). **Sioux Co.:** Badlands, mouth of Monroe Canyon, June 1911 R. W. Dawson (1♂ UNSM); Glen, July 1910 J. T. Zimmer (2♂♂ UNSM); Mitchell, Nov. 1949 (1♀ UNSM). **Thomas Co.:** Halsey, July 1969 UNL Coll. Trip (1? UNSM).

Remarks: Zimmer (1912) reported five male specimens, one from Lincoln, **Lancaster Co.;** one from the bad-lands [sic] of **Sioux Co.;** and three from Glen, **Sioux Co.** This species is easily distinguishable from other members of the genus by its small size and the continuous black stripe on its pronotum. The distribution of this species in North America includes Quebec, Alberta, British Columbia, Newfoundland, Nova Scotia, New Jersey, Manitoba, Missouri, New Mexico, New York, Ohio, Washington, Wyoming, Utah, California, Colorado, Dakota, Illinois, Indiana, Massachusetts, Michigan, Montana, and Saskatchewan (McPherson 1982, Froeschner 1988, Maw et al. 2000).

***Perillus lunatus* knight, 1952 [New State Record]**

Original Nomenclature: *Perillus lunatus* Knight 1952: 230.

Specimen Examined: Sioux Co.: Badlands, mouth of Monroe Canyon, June 1911 R. W. Dawson (1♀ UNSM).

Remarks: This is a relatively rare stink bug species. Neither Blatchley (1926) nor McPherson (1982) reported it. Rider (2012) reported it as occurring in western United States. Its range include Colorado and Montana (Froeschner 1988).

***Podisus brevispinus* Philips, 1992**

Synonyms: *Arma modesta* Dallas 1851: 101.

Podisus modestus Van Duzee 1904: 71.

Podisus brevispinus Phillips 1982: 125.

Remarks: No specimen of this species was available for examination. Its inclusion in this checklist is based on the report of Uhler (1876, as *P. modestus*). This species has a superficial resemblance to the spined-soldier bug, *Podisus maculiventris.* However, it has a short ventral abdominal spine, immaculate legs and rounded humeral angles. Its distribution spans several regions of Canada (Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, and Quebec) and the United States (Colorado, Dakota, Georgia, Iowa, Idaho, Illinois, Indiana, Massachusetts, Maine, Michigan, Montana, North Carolina, New Hampshire, New Mexico, New York, Nebraska, Ohio) (McPherson 1982, Froeschner 1988). Thomas (1992) and Rider (2012) give a summary of the taxonomic history and authority of this species.

***Podisus maculiventris* (Say, 1832)**

Synonyms: *Pentatoma maculiventris* Say 1831: 11.

Podisus (*Podisus) maculiventris* Van Duzee 1904: 71.

Apateticus (*Podisus*) *maculiventris* Zimmer 1912: 19.

Specimens Examined: Adams Co.: Sept. 1987 C. A. Springer (1♂ UNSM). **Antelope Co.:** Neligh, June 1913 L. T. Williams (1? UNSM). **Buffalo Co.:** Gibbon, (1♂ UNSM). **Cass Co.:** South Bend, June 1912 J. T. Zimmer (1♀ UNSM); 5 km E Greenwood, Oct. 2020 K. Koch (1♀). **Clay Co.:** Sept. 1989 M. A. Bowles (1♂ UNSM); Sept. 1989 M. Tharp

(1♀ UNSM); South Central Ag. Lab, Clay Center, Aug. 2017 (2♀♀), July 2019 B. Ademokoya (1♂♂, 3♀♀). **Cuming Co.:** West Point, June 1910 H. S. Smith (1♂, 1♀ UNSM). **Dakota Co.:** South Sioux City, July 1912 L. T. Williams (2♂♂, 1♀ UNSM). **Dawes Co.:** Pine Ridge, July 1910 J. T. Zimmer (1♀ UNSM). **Dixon Co.:** Emerson, June 1913 L. T. Williams (1♂ UNSM) **(This location also spans across Thurston Co. and Dakota Co.);** Haskell Ag. Lab., Concord, Aug. 2017 (1♂♂, 2♀♀), July 2018 (2♀♀), Aug. 2019 B. Ademokoya (1♂, 1♀). **Douglas Co.:** Omaha, Aug. 1912 (1♂ UNSM), July 1913 (1♂, 2♀♀ UNSM), Aug. 1913 L. T. Williams (1♀ UNSM). **Franklin Co.:** June 1978 (1♀ UNSM). **Jefferson Co.:** Sept. 1989 M. A. Bowles (1♂UNSM); June 1991 C. A. Springer (3♂♂, 5♀♀ UNSM). **Lancaster Co.:** Lincoln, Oct. 1892 N. C. Barber (1♀ UNSM); Lincoln, July 1909 C. H. Gable (2♂♂ UNSM); Lincoln, July 1908 (2♂♂ UNSM) (1♀ UNSM); May 1909 (1♀ UNSM), Sept. 1909 (1♂ UNSM), March 1910 (2♂♂ UNSM), July 1913 J. T. Zimmer (1♂ UNSM); Lincoln, July 1910 R. W. Dawson (1♀ UNSM); Lincoln, Aug. 1910 F. A. Burnham (1♀ UNSM); Lincoln, Sept. 1927 W. M. Antes (1♂ UNSM); Lincoln, Oct. 1932 H. A. Hauke (1♀ UNSM); Lincoln, June 1933 D. B. Whelan (3♂♂ UNSM); Lincoln, Aug. 1935 Darlington (1♀ UNSM); Lincoln, Oct. 1947 E. G. Burcham (1♂ UNSM); Lincoln, Aug. 1955 D. W. S. Sutherland (♀UNSM); Lincoln, Aug. 1976 B. C. Ratcliffe (1♀ UNSM); Lincoln, Sept. 2018 L. J. Meinke (1♂); Roca, May (1♀ UNSM). **Madison Co.:** Norfolk, Aug. 1930 L. E. Watson (1♂ UNSM). **Richardson Co.:** Rulo, July 1915 E. M. Partridge (1♂ UNSM); June 1915 E. M. Partridge (♀UNSM); Indian Cake State Park, June 1976 (1♂, 1♀UNSM); Indian Cave State Park, July 1981 A. Reifschneider (1♀ UNSM). **Sarpy Co.:** Childs' point, Sept. 1914 E. M. Partridge (1♀ UNSM). **Saunders Co.:** ENREC, Ithaca, Aug. 2017 (1♂), June 2018 B. Ademokoya

(2♂♂, 3♀♀); ENREC Ithaca, June 2018 (3♂♂, 3♀♀), July 2019 (1♂, 5♀♀), Aug. 2019 E. Knoell (1♂, 1♀); 6 km W Memphis, Oct. 2020 K. Koch (1♂). **Scotts Bluff Co.:** Scotts Bluff, Sept. 1940 R. E. Hill (1♂ UNSM). **Seward Co.:** Nov. 1972 L. J. Meinke (1♀ UNL-ENTO); July 1987 (1♀ UNSM). **Sioux Co.:** Sowbelly Canyon, June 1911 R. W. Dawson (1? UNSM). **Thomas Co.:** Halsey, July 1912 J. T. Zimmer (2♀♀ UNSM).

Remarks: This is probably the most ubiquitous North American Asopine due to its occurrence all over North America (Froeschner 1988, Thomas 1992). Zimmer (1912) reported that this species is common all over the state of Nebraska. He recorded specimens in **Lancaster Co.:** Lincoln, Roca; **South-east Nebraska**; **Cuming Co.:** West Point; **Dawes Co.:** Pines Ridge and **Sioux Co.** It is considered a biological control agent but unreliable due to its generalist feeding habit.

Podisus placidus **Uhler, 1870**

Synonyms: *Podisus placidus* Uhler 1870: 203.

Podisus (*Podisus*) *placidus* Van Duzee 1904: 71

Apateticus (*Podisus*) *placidus* Zimmer 1912:20

Specimens examined. Cass Co.: South Bend, June 1915 L. Bruner (1♀UNSM); South Bend, July 1915 E. G. Anderson (1♀ UNSM). **Cherry Co.**: July 1977 (1♀ UNSM). **Dakota Co.:** South Sioux City, July 1912 L. T. Williams (1♀ UNSM). **Sioux Co.:** Monroe canyon, June 1911 E. W. Dawson (1♀ UNSM); War Bonnet Canyon, Pine Ridge, July L. Bruner (1♀ UNSM).

Remarks: Zimmer (1912) reported a male and two female specimens from **Sioux County.** War Bonnet Canyon, Pine Ridge is currently listed under **Dawes County.** However, Zimmer (1912) specified this location as Sioux County. Froeschner (1988) has a list of the occurrence of this species in North America.

***Rhacognathus americanus* Stål, 1870**

Original Nomenclature: *Rhacognathus americanus* Stål 1870: 33.

Remarks: This species is the only member of the genus *Rhacognathus* that occur in North America. There are no specimens available for observation. However, Uhler (1876) reported it from Nebraska. Its range include Alberta, Manitoba, Illinois, Indiana, Massachusetts, Michigan, Minnesota, Nebraska, and Ohio (Froeschner 1988, Maw et al. 2000).

***Stiretrus anchorago* (Fabricius, 1775) [New State Record]**

Synonyms: *Cimex anchorago* Fabricius 1775: 699.

Stiretrus anchorago: Dallas 1851: 80.

Specimens Examined: Sarpy Co.: Bellevue, Child's Point, Sept. 1909 R. H. Wolcott (1♂ UNSM).

Remarks: This species has a reddish orange form which occurs in all its known ranges. However, the metallic blue form occurs in the Southeast. Child's Point is currently known as Fontenelle Forest. See Froeschner (1988) for the complete list of distribution in North America.

SUBFAMILY EDESSINAE Amyot and Serville, 1843

TRIBE EDESSINI

Ascra bifida (Say, 1831) [New State Record]

Synonyms: *Pentatoma* (*Ascra*) *bifida* Say 1932: 322.

Edessa bifida Stål 1872: 58.

Edessa florida Santos et al. 2015: 445-470.

Specimens Examined: Lancaster Co.: Lincoln, July 2004 S. Buchholz (1♂ UNL-ENTO).

Remarks: This species is known to occur in the southeast. Its distribution includes Florida, Louisiana, Maryland, Arkansas, and Texas (Froeschner 1988). Additional locations are Arizona, California, South Carolina, North Carolina, and Virginia (Santos et al. 2015, Rider 2020 Pentatomoidea home page). The report of Barton and Lee (1984) in Arkansas is the closest to Nebraska this species has been reported. Based on occurrence data, this single specimen found in Nebraska is probably an adventive find. McPherson (1982) ascribed this subfamily and tribe to Kirkaldy while Froeschner (1988) did not designate a tribal rank but ascribed the subfamily to Amyot and Serville. Rolston and McDonald (1979) elevated this group from tribe to subfamily. Both McPherson (1982) and Froeschner (1988) reported a second species, *Edessa florida* Barber, occurring in southeastern United States. However, this species is now considered a junior synonym of *A. bifida* (Santos et al. 2015).

SUBFAMILY PENTATOMINAE Leach, 1815

TRIBE AELIINI Douglas and Scott, 1865

Aelia Americana Dallas, 1851

Original Nomenclature: *Aelia americana* Dallas 1851: 223.

Specimens Examined: Lancaster Co.: Lincoln, July 1908 J. T. Zimmer (1♂ UNSM); Lincoln July 2004 E. Reike (1♂ UNL-ENTO). **Lincoln Co.:** North Platte, June 1942 H. D. Tate (1♀ UNSM).

Remark: This species is usually associated with grassy habitats. Zimmer (1912) reported a male specimen collected in Lincoln, **Lancaster County** in July 1908**.** See McPherson (1982) and Froeschner (1988) for distribution information in North America.

Neottiglossa sulcifrons Stål, 1872

Synonyms: *Neottiglossa* (*Melanostoma*) *sulcifrons* Stål 1872: 18.

Neottiglossa sulcifrons Zimmer 1912: 12.

Specimens Examined: Cherry Co.: June 1968 UNL Coll. Trip (1♀ UNSM). **Dawes Co.:** June 1954 H. J. Ball (1♂ UNSM). **Sioux Co.:** Glen, July 1910 J. T. Zimmer (4♂♂, 1♀ UNSM); Aug. 1963 R. E. White (1♀ UNSM); Monroe Canyon. July 1971 (1♀ UNSM).

Remarks: Zimmer (1912) reported one female specimen of this species from Lincoln, **Lancaster Co.,** and two males and three females from Halsey, **Thomas Co.**

Neottiglossa trilineata (Kirby, 1837)

Synonyms: *Pentatoma* (*Neottiglossa*) *trilineata* Kirby 1837: 276.

Neottiglossa undata trilineata Zimmer 1912: 12.

Remark: This species is listed based on the report of Uhler (1877). No specimen was available for examination. Its distribution in North America includes Alberta, British Columbia, Manitoba, Nova Scotia, Saskatchewan, Quebec, California, Colorado, Dakota, Michigan, Nebraska (McPherson 1982, Froeschner 1988) and recently reported in Minnesota (Koch et al. 2014).

***Neottiglossa undata* (Say 1832)**

Synonyms: *Pentatoma undata* Say 1832: 8.

Neottiglossa (*Neottiglossa*) *undata* Kirkaldy 1909: 80.

Specimens Examined: Chase Co.: Imperial, Sept. 1961 Crew (10♂♂, 7♀♀ UNSM). **Cherry Co.:** Valentine wildlife refuge, June 1968 UNL Coll. Trip (1♀ UNSM). **Douglas Co.:** Omaha, July 1913 L. T. Williams (1♂ UNSM). **Fillmore Co.:** Fairmont, June 1914 G. W. Deming (1♀ UNSM). **Grant Co.:** Hyannis, Sept. 1961 Crew (1♂, 1♀ UNSM). **Hall Co.:** Alda, Aug. 1958 (1♀ UNSM). **Keith Co.:** Cedar Point Biological Station, July 1984 B. C. Ratcliffe (1♀ UNSM). **Lancaster Co.:** Lincoln, Oct. 1914 G. W. Deming (1♂ UNSM); Lincoln, Oct. 1947 E. G. Burcham (1♂ UNSM); Lincoln, June (1♀ UNSM). **McPherson Co.:** Sand Hills Ag. Lab., July 1973 (8♂♂, 5♀♀ UNSM). **Saline Co.:** Crete, May 1955 L. W. Quate (1♂, 1♀ UNSM). **Thomas Co.:** Halsey June 1911 J. T. Zimmer (1♂, 3♀♀ UNSM); June 1969 UNL Coll. Trip (1♀ UNSM).

Remarks: Additional locations in Nebraska include Warbonnet Canyon, May 1901 L. Bruner (1♀) and Glen, July 1910 J. T. Zimmer (5♂♂, 1♀). Both locations are in **Sioux county.** See McPherson (1982) and Froeschner (1988) for distribution range in North America.

TRIBE AGONOSCELIDINI

Agonoscelis puberula Stål, 1954 [New State Record]

Synonyms: *Agonoscelis brevicornis* Jensen-Haarup 1920: 216.

Agonoscelis puberula Stål 1954: 216.

Specimens Examined: Lancaster Co.: Lincoln, Oct. 2002 J. N. Russ (1♀ UNL-ENTO).

Remark: This very pubescent species, commonly called the African cluster bug, is one of the new exotic additions to the stink bug fauna of the New World. Native to Africa, it was first reported in the United States in Arizona in 1990. Its distribution in the United States include Arizona, New Mexico, Texas (Thomas et al. 2003), and more recently, Minnesota (Koch et al. 2014). Tribal placement in this genus is debatable. Thomas et al. (2013) posits that member of the genus *Agonoscelis* should be in the same tribe with the genus *Trichopepla*. An additional specimen (1♂ UNL-ENTO) without label information was examined.

TRIBE CAPPAEINI Atkinson, 1888

Halyomorpha halys (Stål, 1855) [New State Record]

Synonym: *Pentatoma halys* Stål 1855: 182.

Specimens Examined: Cass Co.: 5 Km East of Greenwood, Sept. 2020 K. Koch (5♀♀). **Dixon Co.:** Concord, Sept. 2019 B. Ademokoya (1♂). **Lancaster Co.:** Lincoln, March 2017 D. Olsen (1♂ UNL-ENTO); Lincoln, UNL East Campus, Aug. 2019 B. Ademokoya (1♀); Lincoln, Aug. 2020 Haley Parker (1♀ UNL-ENTO); Lincoln, UNL East Campus, Sept. 2020 (23♂♂, 27♀♀), Oct. 2020 K. Koch (4♂♂, 7♀♀); Lincoln, UNL East Campus Aug. 2021 B. Ademokoya (1♀).

Remarks: This is another addition to North America stink bug fauna. It was first reported in Pennsylvania in the mid-1990s (Hoebeke and Carter 2003). From the point of first interception, it has spread to over 30 states in the United States (Leskey et al. 2012), as well as Ontario and Quebec in Canada (Fogain and Graff 2011). It is an established pest of orchards in the Mid-Atlantic region.

TRIBE CARPOCORINI Mulsant and Rey, 1866

Antheminia remota (Horvath, 1908)

Synonyms: *Carpocoris remotus* Horvath 1907: 296.

Carpocoris (*Antheminia*) *remotus* Zimmer 1912: 6.

Specimens Examined: Dundy Co.: Haigler, May 1914 L. M. Gates (2♂♂ UNSM).

Remarks: Zimmer (1912) reported three (3♀♀) specimens from **Sioux County** collected in May and early June.

Coenus delius (Say, 1832)

Synonyms: *Pentatoma delia* Say 1831: 8.

Coenus delius Zimmer 1912: 11.

Specimens Examined: Arthur Co.: Aug. 1984 B. C. Ratcliffe (1♂ UNSM). **Cass Co.:** Near Plattsmouth, July 1995 M. L. Jameson (1♀ UNSM). **Cuming Co.:** West Point, June 1888 (3♀♀ UNSM). **Custer Co.:** Milburn, Aug. 1970 (1♂, 1♀ UNSM). **Dawes Co.:** Marsland, June 1954 L. W. Quate (1♀ UNSM). **Douglas Co.:** Omaha, July 1913 L. T. Williams (1♀ UNSM); Bennington, June 1957 S. D. Carlson (1♂ UNSM). **Franklin Co.:** June 1978 (1♂ UNSM). **Grant Co.:** Whitman, Sept. 1954 L. W. Quate (1♀ UNSM). **Holt**

Co.: (1♂, 1♀). **Keya Paha Co.:** Carns, Aug. 1902 W. D. Pierce (1♀). **Lancaster Co.:** Lincoln, March 1910 W. Rands (1♂ UNSM); March (1♂, 1♀ UNSM); June 1989 M. L. Jameson (1♀ UNSM). **Lincoln Co.:** North Platte, June 1971 (1♀ UNSM). **Saunders Co.:** ENREC, Ithaca, Sept. 2017 B. Ademokoya (1♀); ENREC, Ithaca, June. 2018 B. Ademokoya & T. Omtvedt (1♀); ENREC, Ithaca, July 2019 B. Ademokoya & R. Stacke (1♂, 2♀♀). **Sheridan Co.:** Sand Hills, July (1♂, 1♀ UNSM). **Thomas Co.:** Halsey, Aug. 1958 R. Henzlik (1♀ UNSM); Aug. 1969 (1♂, 1♀ UNSM).

Remarks: In addition to some of the listed counties, Zimmer (1912) reported specimens from Red Cloud, **Webster County** and **"Western Nebraska".** See McPherson (1982) and Froeschner (1988) for distribution in North America.

Cosmopepla lintneriana Kirkaldy, 1909

Synonyms: *Cosmopepla bimaculata* Thomas 1865: 455

Cosmopepla lintneriana Kirkaldy 1909: 80.

Specimens Examined: Antelope Co.: Neligh, June 1909 J. T. Zimmer (1♀ UNSM). **Cass Co.:** Louisville, July 1914 E. G. Anderson (1♂, 1♀ UNSM). **Cherry Co.:** Valentine wildlife refuge, June 1968 UNL Coll. Trip (1♀ UNSM). **Custer Co.:** Milburn, Aug. 1970 (2♂♂, 1♀ UNSM); (1♂ UNSM). **Douglas Co.:** Omaha, June 1913 L. T. Williams (1♂ UNSM). **Garfield Co.:** J. Lambert (2♂♂, 2♀♀ UNL-ENTO). **Holt Co.:** Spencer Dam, June 1974 (12♂♂, 15♀♀ UNSM). **Lancaster Co.:** July 1900 (1♂ UNSM); Roca, May 1911 Pool (1♀ UNSM); Sept. 1977 R. Luna (1♀ UNL-ENTO); Aug. 1991 M. E. Jameson (2♂♂, 2♀♀ UNSM); Aug. 2002 A. Alves (2♂♂, 1♀ UNL-ENTO); Lincoln, Sept. 2003 R. E. Denton (1♀ UNL-ENTO); Aug. 2004 C. Roberts (1♀ UNL-ENTO), Lincoln, Aug.

2004 C. Hobson (1♀ UNL-ENTO); Oct. 2006 S. A. Palizada (1♂, 1♀ UNL-ENTO); July 2008 K. Tangtrakulwanich (1♀ UNL-ENTO); Lincoln, June R. H. Wolcott (4♂♂, 1♀ UNSM); Sept. (2♀♀ UNSM). **Saline Co.:** Swanton, Aug. 1987 Robert Chamberlain (1♀ UNSM). **Nemaha Co.:** Brownville, Aug. 2004 Marilyn Woerth (1♂, 1♀ UNL-ENTO). **Otoe Co.:** Palmyra, Aug. 2004 K. Gilbert, on sunflower (1♀ UNL-ENTO). **Sarpy Co.:** La Platte, June 1957 L. W. Quate (1♂, 1♀ UNSM). **Saunders Co.:** Morse Bluffs, June 1955 L. W. Quate (1♀ UNSM); ENREC Ithaca, Aug. 2017 (1♂, 3♀♀), Sept. 2017 B. Ademokoya (1♀). **Sioux Co.:** Monroe Canyon, June 1911 R. W. Dawson (1♂, 3♀♀ UNSM); Glen canyon, Aug. 1959 UNL Museum Entomology Expedition (1♂ UNSM); Monroe Canyon, July 1971 (4♂♂, 2♀♀ UNSM); Sept. 1996 S. Budak (1♀ UNL-ENTO). **Thurston Co.:** Walthill, Aug. 1944 Geo. Gregory (1♀ UNSM).

Remarks: This species, commonly called the twice-stabbed stink bug is distinguishable by its small size, black color and the unique red or orange pronotal stripes and scutellar markings. It is widely distributed throughout North America (McPherson 1982, Froeschner 1988).

Cosmopepla uhleri Montandon, 1893

Original Nomenclature: *Cosmopepla uhleri* Montandon 1893: 48

Specimen Examined: Sioux Co.: (1♀ UNSM).

Remarks: This specimen is probably the same specimen examined by Zimmer (1912). He reported a single female labeled "Sioux County, Nebraska". Froeschner (1988) noted that this species was erroneously reported for Nebraska, "Literature record for Neb. was a *lapsus* for Nev.”. This single specimen, although with incomplete label information shows that this species occurs in Nebraska.

Euschistus ictericus (Linnaeus, 1763)

Synonyms: *Cimex ictericus* Linnaeus 1763: 16.

Euschistus ictericus Dallas 1851: 206.

Specimens Examined: Antelope Co.: Neligh, June 1909 W. Thompson (1♀ UNSM). **Custer Co.:** Milburn, Aug. 1970 (1♀ UNSM). **Grant Co.:** Hyannis, Sept. 1961 G. Stokes (1♂, 1♀ UNSM). **Lancaster Co.:** Lincoln, June 1910 J. T. Zimmer (1♀ UNSM). **Lincoln Co.:** North Platte Aug. 1971 (1♀ UNSM). **Sarpy Co.:** Omaha, Child’s point, Oct. 1923 Owen Bryant (1♂ UNSM). **Scotts Bluff Co.:** Mitchell, July 1914 L. M. Gates (1♀ UNSM).

Remarks: This species can be separated from other members of the genus *Euschistus* by the callused line that runs between the humeral spines and black spiracular peritremes. The distribution is given as Arkansas, Colorado, Connecticut, Florida, Iowa, Illinois, Indiana, Louisiana, Massachusetts, Michigan, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Rhode Island, Texas, Utah, Vermont, Wisconsin, Ontario (Froeschner 1988), Quebec (Paiero 2013), Minnesota and North Dakota (Rider 2012).

Euschistus latimarginatus Zimmer, 1910

Original Nomenclature: *Euschistus latimarginatus* Zimmer 1910: 167.

Specimens Examined: Arthur Co.: Arapaho prairie Aug. 1984 B. C. Ratcliffe (2♂♂ UNSM). **Chase Co.:** Imperial, Aug. 1961 Crew (1♂ UNSM). **Hooker Co.:** Dismal River, July (1♀ UNSM). **Lancaster Co.:** Lincoln, Oct. 1910 (1♀ UNSM). **Lincoln Co.:** Brady

Island, May 1896 (1♀ UNSM). **Thomas Co.:** Halsey, June 1911 (2♀♀ UNSM), Aug. 1911 J. T. Zimmer (13♂♂, 18♀♀ UNSM); Halsey, Aug. 1920 C. B. Philip (2♂♂ UNSM); Halsey, Aug. Sept. 1957 (3♂♂, 1♀ UNSM), June 1958 (2♂♂, 2♀♀ UNSM), Sept. 1958 R. Henzlik (13♂♂ UNSM); June 1971 (2♂♂, 5♀♀ UNSM); Halsey, Aug. 1969 UNL Coll. Trip (4♂♂, 5♀♀ UNSM). **McPherson Co.:** Sandhills Ag. Lab. Aug. 1973 (1♀ UNSM).

Remarks: This species was first described in Nebraska. It can easily be distinguished from other *Euschistus* species found in this locality by its immaculate connexivum. Zimmer (1912) reported specimens from **Cherry County;** Dismal River, **Hooker County;** Brady Island, **Lincoln County;** Halsey, **Thomas County;** and Lincoln, **Lancaster County.** Its distribution in North America includes Colorado, Nebraska, Kansas, Minnesota, and North Dakota (Zimmer 1912, Froeschner 1988, Rider 2012, Koch et al. 2014).

***Euschistus servus euschistoides* (Vollenhoven, 1868)**

Synonyms: *Diceraeus euschistoides* Vollenhoven 1868: 180.

Euschistus fissilis Zimmer 1912: 9.

Specimens Examined: Cass Co.: Louisville, July 1914 (1♀ UNSM), Aug. 1914 E. G. Anderson (1♂ UNSM). **Clay Co.:** South Central Ag. Lab, Clay Center, Sept. 2018 B. Ademokoya (1♀). **Dakota Co.:** South Sioux City, Aug. 1912 L. T. Williams (1♀ UNSM). **Dawes Co.:** (1♀ UNSM). **Douglas Co.:** Omaha, July 1913 (2♂♂ UNSM), Aug. 1913 L. T. Williams (2♀♀, 1♂ UNSM). **Richardson Co.:** Rulo, June 1915 L. Bruner (1♀ UNSM); Rulo, June 1915 E. M. Partridge (1♀ UNSM). **Saunders Co.:** ENREC, Ithaca, Aug. 2017 (1♀), Sept. 2018 B. Ademokoya (1♀). **Thomas Co.:** Halsey, July 1969 UNL Coll. Trip (1♀ UNSM).

Remarks: *Euschistus servus euschistoides* and *E. servus servus* are subspecies of the brown stink bug, *Euschistus servus*. *Euschistus servus euschistoides* is said to be more northern in distribution. In this species, the juga are distinctly longer than the tylus, last two antennal segments are dark brown and the connexivum is unexposed (Paier et al. 2013). Two of the specimens collected from **Saunders County** have a mix of the characteristics of both subspecies. These specimens represent the intergrades reported by McPherson (1982). The distribution of this hybrid population occurs from Kansas to Maryland.

Euschistus servus servus **(Say, 1832) [New State Record]**

Synonyms: *Pentatoma serva* Say 1832: 4.

Euschistus (*Euschistus*) *impictiventris* Stål 1872: 26.

Specimens Examined. Dixon Co.: Haskell Ag. Lab, Concord, July 2017 B. Ademokoya (2♀). **Franklin Co.:** June 1978 (1♂ UNSM). **Lancaster Co.:** Lincoln Sept. 2015 V. Valentine (1♀ UNL-ENTO); Pioneers Park, Lincoln, April 2018 I. Pepitone (1♂ UNL-ENTO). **Sioux Co.:** July 1910 J. T. Zimmer (1♂ UNSM); June 1911 R. W. Dawson (1♂, 1♀ UNSM); Wood Reserve, Ft. Robinson W. T. Atyeo (1♂ UNSM).

Remarks: As opposed to *E. servus euchistoides*, this species has the juga and tylus subequal in length, the last two antennal segments are yellowish-brown or reddish-brown and the connexivum is broadly exposed (Paiero et al. 2013).

Euschistus tristigmus luridus Dallas, 1851

Synonyms: *Euschistus luridus* Dallas 1851: 207.

Euschistus tristigmus luridus Van Duzee 1904: 47.

Specimens Examined. Cass Co.: Weeping water, Sept. 1909 J. T. Zimmer (1♂, 1♀ UNSM). **Dawes Co.:** Crawford, Sept. 1911 J. T. Zimmer (1♀ UNSM); War Bonnet Canyon (1♀ UNSM). **Douglas Co.:** Omaha, July 1913 L. T. Williams (1♀ UNSM). **Dixon Co.:** Haskell Ag. Lab, Concord Aug. 2017 B. Ademokoya (1♀). **Lancaster Co.:** Lincoln, June 1910 (2♀♀ UNSM), June J. T. Zimmer (1♀ UNSM); Lincoln Sept. 2004 L. C. Magalhaes (1♀UNL-ENTO). **Lincoln Co.:** Sutherland, Aug. 1947 E. G. Burcham (1♀ UNSM). **Sarpy County:** Omaha, Child's point, Oct. 1923 Owen Bryant (1♂ UNSM). **Saunders Co.:** ENREC Ithaca, Sept. 2017 (2♀♀), Aug. 2019 B. Ademokoya and R. Stacke (1♂, 1♀). **Sioux Co.:** July 1913 L. T. Williams (1♀ UNSM); July 1971 (1♀ UNSM); (2♂♂, 1♀ UNSM).

Euschistus tristigmus tristigmus (Say, 1832) [New State Record]

Synonyms: *Pentatoma tristigma* Say 1831: 4.

Euschistus tristigmus var. *pyrrhocerus* Van Duzee 1904: 47.

Specimens Examined. Cass Co.: Weeping water, Sept. 1909 J. T. Zimmer (1♀ UNSM); 5 km E Greenwood, Sept. 2020 K. Koch (1♀), Oct. 2020 K. Koch (1♀) (♀). **Dixon Co.:** Haskell Ag. Lab, Concord July 2017 B. Ademokoya (1♀). **Hamilton Co.:** Aurora Aug. 2002 K. Y. Bontrager (1♀ UNL-ENTO). **Lancaster Co.:** Lincoln, Oct. 1947 E. G. Burcham (1♂ UNSM); May 1989 M. L. Jameson (1♀ UNSM); April 2016 Kylie Ham (1♂ UNL-

ENTO). **Nemaha Co.:** Aug 2021 B. Ademokoya (1♂). **Saunders Co.:** ENREC Ithaca Aug. 2018 (1♀), Sept. 2018 B. Ademokoya and T. Omtvedt (2♀♀).

Remarks: *Euschistus t. luridus* and *E. t. tristigmus* are subspecies of the dusky sting bug. These stink bug species can be distinguished from other *Euschistus* species by the presence of a row of dark markings along the midline of the abdominal venter. The humeral angles are rounded in *Euschistus t. luridus* and acute to spinose in *Euschistus t. tristigmus.* The former occurs in the northern United States while the latter is southern in distribution (McPherson 1982). However, both subspecies occur in Nebraska. Zimmer (1912) reported this species as *Euschistus tristigmus* but a look at the specimens he examined and/or collected showed that both subspecies were represented in his collection. See McPherson (1982) and Froeschner (1988) for the distribution of these species in North America.

Euschistus variolarius (Palisot de Beauvois, 1857)

Synonyms: *Pentatoma variolaria* Palisot de Beauvois 1817: 149.

Euschistus variolarius Stål 1872: 26.

Specimens Examined: Arthur Co.: Aug. 1984 B. C. Ratcliffe (2♀♀ UNSM). **Cass Co.:** Louisville, July 1914 E. G. Anderson (1♂, 3♀♀ UNSM); South Bend, June 1915 E. G. Anderson (1♂ UNSM); Louisville, July 1914 H. A. Jones (6♀♀ UNSM). **Cherry Co.:** June 2019 B. Thomas (1♂). **Clay Co.:** Sept. 1989 M. A. Bowles (2♂♂ UNSM); Sept. 1989 M. Tharp (1♂ UNSM); Aug. 2017 (3♂♂, 3♀♀), July 2018 (13♂♂, 10♀♀), June 2019 B. Ademokoya & R. Stacke (10♂♂, 10♀♀); May 2018 E. Knoell (5♂♂, 3♀♀). **Cuming Co.:** West Point, Aug 1887 (1♀ UNSM); June 1888 (4♂♂, 1♀ UNSM). **Custer Co.:** Aug. 1970

(1♂ UNSM). **Dakota Co.:** South Sioux City, July 1912 (1♂, 3♀♀ UNSM), Aug. 1912 L. T. Williams (1♂ UNSM). **Douglas Co.:** Omaha, July 1913 L. T. Williams (2♂♂, 6♀♀ UNSM); Omaha, Oct. 1923 Owen Bryant (2♀♀ UNSM); Omaha, Aug. 1938 E. C. Klostermeyer (1♀ UNSM). **Dixon Co.:** Aug. 2017 (7♂♂, 12♀♀), June 2018 (5♂♂, 4♀♀), June 2019 B. Ademokoya (5♂♂, 12♀♀). **Fillmore Co.:** Fairmont, July 1914 G. W. Deming (1♂, 1♀ UNSM). **Holt Co.:** June 1974 (1♂, 1♀ UNSM). **Johnson Co.:** Tecumseh Oct. 1979 J. Pickerill (1♂ UNL-ENTO). **Lancaster Co.:** Lincoln, May 1908 (1♂ UNSM); Lincoln, June 1908 (1♂ UNSM), July 1908 (7♂♂, 7♀♀ UNSM), Sept. 1908 (2♀♀ UNSM) July 1909 (1♂, 5♀♀ UNSM), Aug. 1909 (1♀ UNSM), Sept. 1909 (6♂♂, 3♀♀ UNSM), March 1910 (1♂, 1♀ UNSM), May 1910 (2♀♀ UNSM), July 1910 (1♂, 4♀♀ UNSM), Aug 1910 (1♀ UNSM), June 1911 J. T. Zimmer (1♂, 8♀♀ UNSM); Lincoln, June 1908 C. H. Gable (1♂ UNSM); Roca, April 1909 R. H. Wolcott (1♂ UNSM); Lincoln, July 1909 F. A. Burnham (1♂, 2♀♀ UNSM); Roca, May 1912 L. Bruner (1♂ UNSM); Roca July 1912 L. M. Gates (1♀ UNSM); June 1914 G. W. Deming (1♂ UNSM); Lincoln, Aug 1916 J. H. Powers (1♀ UNSM); Lincoln, July 1921 R. E. Weir (1♀ UNSM); Lincoln, June 1923 C. B. Philip (1♀ UNSM); Lincoln, July 1947 E. G. Burcham (1♀ UNSM); Sept. 1952 P. McClymont (1♀ UNSM); Sept. 1952 R. Haupt (1♂ UNSM); Sept. 1952 W. Stevens (1♂, 2♀♀ UNSM); April 1954 D. W. Alpuerto (1♂ UNSM); Sept. 1956 D. L. Silhacek (1♀ UNSM); July 1980 Ian Ratcliffe (1♀ UNSM); Lincoln, Sept. 2002 G. L. Humphrey (1♂ UNL-ENTO); Lincoln, Sept. 2003, R. D. Goertzen (1♂ UNL-ENTO); Sept. 2004 L. Pierson (1♀ UNL-ENTO); Malcolm, July 2004 D. Duckett (1♂ UNL-ENTO); Lincoln, May 2013 Ivy M. Orellana (1♀ UNL-ENTO); Spring Creek Prairie June 2015 K. M. Chapman (1♀ UNSM); Sept. 2018 L. J. Meinke (1♂); East Campus UNL, May 2019 B.

Ademokoya (10♂♂, 10♀♀). **Lincoln Co.:** North Platte, July 1971 (1♀ UNSM). **Loup Co.:** July 1996 C & K Messenger (1♂ UNSM) (1♀ UNSM). **Morrill Co.:** June 2019 B. Thomas (1♀). **Nemaha Co.:** Indian Cave State Park, June 2013 G. Cooper (1♀ UNL-ENTO). **Red Willow Co.:** Indianola, May (1♂ UNSM); **Richardson Co.:** Rulo, June 1915 E. M. Partridge (1♂ UNSM); Rulo, June 1915 L Bruner (1♂ UNSM); June 1976 (1♂, 1♀ UNSM). **Saline Co.:** Crete, May 1915 E. M. Partridge (1♂ UNSM). **Sarpy Co.:** Aug. 1968 B. C. Ratcliffe (1♀ UNSM). **Saunders Co.:** Ashland, June 1913 L. M. Gates (1♀ UNSM); Ashland, (1♂ UNSM); Malmo, Oct. 2000, J. P. Speichinger (1♀ UNL-ENTO); ENREC Ithaca, July 2017 (2♀♀), Aug. 2017 B. Ademokoya (8♂♂, 10♀♀); July 2018 B. Ademokoya & T. Omtvedt (10♂♂, 10♀♀); May 2018 (1♂), June 2018 E. Knoell (5♂♂, 5♀♀); July 2019 B. Ademokoya & R. Stacke (6♂♂, 5♀♀); 6 km W Memphis, Sept. 2020 K. Koch (1♀). **Seward Co.:** July 1987 (2♂♂, 3♀♀ UNSM). **Thomas Co.:** Halsey, July 1969 UNL Coll. Trip (1♀ UNSM).

Remarks: This is the prevalent *Euschistus* species and the most abundant stink bug species in eastern Nebraska. Zimmer (1912) reported specimens from only the eastern part of Nebraska, however, we report specimens from the west. Males of *Euschistus variolarius* are easily recognized by the presence of a prominent dark spot on the pygophore.

***Holcostethus abbreviatus* Uhler, 1872**

Synonyms: *Holcostethus abbreviatus* Uhler 1872: 397

Peribalus abbreviatus Van Duzee 1904: 33.

Specimens examined. Clay Co.: South Central Ag. Lab, Clay Center, B. Ademokoya (1♀). **Dawes Co.:** Warbonnet Canyon, L. Bruner (1♀ UNSM). **Lancaster Co.:** Lincoln, Oct.

2004 B. N. Belzer (1♀ UNL-ENTO). **Sioux Co.:** July 1910 J. T. Zimmer (1♀ UNSM). **Thomas Co.:** Halsey, July 1969 UNL Coll. Trip (1♀ UNSM).

Remarks: Zimmer (1912) reported females (4 ♀♀) of this species from Hogan's Bridge, **Holt County**; Crawford, **Dawes County;** Warbonnet Canyon and Glen in **Sioux County.** Froeschner (1988) reports the distribution of this species in North America as Alberta, Arizona, British Columbia, California, Colorado, Iowa, Idaho, Kansas, Montana, Nebraska, New Mexico, Nevada, North Dakota, Oregon, South Carolina, Utah, Washington. See McPherson (1982) and Rider (2012) for the description of the *Holcostethus* species that occur in the Midwest.

Holcostethus fulvipes **(Ruckes 1957) [New State Record]**

Synonyms: *Peribalus fulvipes* Ruckes 1957: 39.

Holcostethus fulvipes McDonald 1975: 254.

Specimen Examined: Saunders Co.: ENREC Ithaca, June 2019 B. Ademokoya (1♀).

Remarks: The distribution of this species is given as Michigan, New Hampshire, and New York (McPherson 1982). It can be separated from *H. abbreviatus* by the presence of longitudinal zig-zag patterns on the abdomen and the gap between the jugal apices (McPherson 1982).

Holcostethus limbolarius **(Stål, 1872)**

Synonyms: *Peribalus limbolarius* Stål 1872: 34.

Holcostethus limbolarius Kirkaldy 1909: 48.

Specimens examined. Antelope Co.: Clearwater, Sept. 1914 (1♂ UNSM). **Banner Co.:** Sept. 1983 (1♂, 2♀♀ UNL-ENTO). **Box Butte Co.:** Alliance, Aug 1940 R. E. Hill (1♂ UNSM). **Cass Co.:** March 1910 J. T. Zimmer (1♂ UNSM); Louisville, July 1914 E. G. Anderson (1♀ UNSM); Louisville, July 1914 H. A. Jones (1♀ UNSM); 5 km E Greenwood, Oct. 2020 K. Koch (1♂). **Chase Co.:** Imperial, July 1911 J. T. Zimmer (2♂♂, 1♀ UNSM). **Cherry Co.:** June 2019 B. Thomas (1♂, 1♀). **Cheyenne Co.:** June 2019 B. Thomas (1♀, 1♂). **Clay Co.:** South Central Ag. Lab., Clay center, Aug. 2018 B. Ademokoya (1♂). **Cuming Co.:** West Point, Sept 1887 (1♂ UNSM). **Custer Co.:** Aug. 1979 (3♂♂, 1♀ UNSM). **Dawson Co.:** Lexington, Aug. 1923 A. R. Hecht (11♂♂, 11♀♀ UNSM). **Dixon Co.:** Haskell Ag. Lab., Concord, Aug. 2017 B. Ademokoya (1♀). **Douglas Co.:** Omaha, Aug. 1913 (1♂ UNSM); Aug. 1914 L. T. Williams (1♀ UNSM); Omaha, Aug. 1937 E. C. Klostermeyer (2♂♂ UNSM). **Dundy Co.:** Haigler, July 1911 J. T. Zimmer (1♂ UNSM). **Franklin Co.:** Franklin, June 1978 (1♀ UNSM). **Garden Co.:** Oshkosh, Aug. 1955 L. W. Quate (1♀ UNSM). **Holt Co.:** Sept. 1960 (1♀ UNSM). **Lancaster Co.:** Lincoln, Oct. 1892 H. Barber (1♀ UNSM); Lincoln, Sept 1909 (6♂♂, 5♀♀ UNSM), July 1908 (2♀♀ UNSM), May 1909 (1♀ UNSM), Oct. 1909 (8♂♂, 7♀♀ UNSM), March 1910 (1♂ UNSM), June 1911 J. T. Zimmer (2♂♂, 1♀ UNSM); Lincoln, July 1909 C. H. Gable (1♀ UNSM); Malcolm, April 1909 (1♀ UNSM), Oct. 1909 C. R. Oertel (2♂♂ UNSM); Lincoln, Aug. 1910 F. A. Burnham (1♂ UNSM); Lincoln, June 1911 G. M. Gates (1♀ UNSM); Lincoln, Oct. 1912 L. Bruner (1♀ UNSM); Lincoln, Aug. 1913 (1♀ UNSM), June 1914 D. W. Deming (1♀ UNSM); Lincoln, Oct. 1923 Owen Bryant (1♂, 1♀ UNSM); Lincoln, Feb. 1927 R. H. Wolcott (1♀ UNSM); Lincoln, Sept. 1928 Hansel Phipps (1♂ UNSM); Lincoln, April 1929 Fred V. Gray (1♀ UNSM); Lincoln, April 1932 Hill (1♀ UNSM); Lincoln, Aug.

1932 H. A. Hauke (2♂♂ UNSM); Lincoln, Sept. 1932 (1♀ UNSM), Oct. 1932 J. C. Gollehon (1♂, 5♀♀ UNSM); Lincoln, June 1935 (1♂ UNSM), June 1937 Roberts & Hill (1♀ UNSM); Lincoln, Aug. 1940 H. D. Tate (2♀♀ UNSM); Oct. 1947 E. G. Burcham (1♂, 1♀ UNSM); Lincoln, Sept. 1952 R. Haupt (1♂, 1♀ UNSM); Lincoln, Sept. 2002 K. Y. Bontrager (1♂ UNL-ENTO); Sept. 2003 K. P. Jeffries (1♂ UNL-ENTO); Lincoln, Sept. 2003 R. E. Denton (1♀ UNL-ENTO); July 2004 C. Hobson (1♀ UNL-ENTO); East Campus UNL Sept. 2018 L. J. Meinke (1♀). **McPherson Co.:** July 1973 (1♂, 2♀♀ UNSM). **Richardson Co.:** June 1976 (1♂ UNSM). **Saunders Co.:** June 1985 L. J. Meinke (1♀ UNL-ENTO); ENREC, Ithaca, June 2019 B. Ademokoya (1♂, 3♀♀); 9.5 km S Fremont, Oct. 2020 K. Koch (1♀). **Sioux Co.:** Aug. 1905 (1♀ UNSM); Mitchell, July 1912 L. M. Gates (1♀ UNSM); Aug. 1912 L. T. Williams (1♀ UNSM). **Thomas Co.:** Halsey, June 1911 J. T. Zimmer (1♂, 2♀♀ UNSM); Halsey, Sept. 1958 R. Henzlik (1♂, 2♀♀ UNSM).

Remarks: This is the most common species of *Holcostethus* in Nebraska. Zimmer (1912) reported specimens from Lincoln, Roca, and Malcolm in **Lancaster County;** Weeping Water and Nehawka in **Cass County;** West Point in **Cuming County;** Cedar Bluffs in **Saunders County;** and **Sioux County.** The connexiva in this species is bordered by narrow yellow margin and the abdominal venter lack the zig-zag pattern present in *H. fulvipes.* Although some of the specimens examined have some degree of abdominal pattern. This species is widely distributed through the United States and Canada (McPherson 1982, Froeschner 1988)

Holcostethus macdonaldi Rider and Rolston, 1995 [New State Record]

Synonyms: *Pentatoma picea* Dallas 1851: 236.

Holcostethus piceus Kirkaldy 1909: 48.

Specimens Examined: Sioux Co.: July 1971 (1♀ UNSM); Aug. 1971 (1♀ UNSM).

Remarks: A characteristic that easily separate this species from other members of the genus that occur in the Midwest is the possession of darkened abdominal venter. Its distribution includes Alberta, Colorado, Iowa, Illinois, Manitoba, Michigan, Montana, Ontario, Quebec, South Dakota, Saskatchewan (Froeschner 1988), North Dakota (Rider 2012) and Minnesota (Koch et al. 2014).

Hymenarcys nervosa (Say, 1832)

Synonyms: *Pentatoma nervosa* Say 1831: 9.

Hymenarcys nervosa Zimmer 1912: 11.

Specimen Examined: Lancaster Co.: Roca, March 1911 R. T. Schleuter (1♀ UNSM).

Remarks: There is no additional reported specimen of species recovered from Nebraska since 1911. This specimen from Roca remains the only representative of this species found in the state. Although Zimmer (1912) reported this species, Froeschner (1988) did not report it for Nebraska. It was recently reported for Kansas (Packauskas 2012). See Froeschner (1988) for other distribution locations.

Mcphersonarcys aequalis (Say, 1832)

Synonyms: *Pentatoma aequalis* Say 1831: 7.

Hymenarcys aequalis Zimmer 1912: 11.

Mcphersonarcys aequalis Thomas 2012: 127.

Specimens Examined: Lancaster Co.: Lincoln, March (4♂♂, 5♀♀ UNSM); Roca, April (1♂ UNSM); Lincoln, Sept. 1892 (1♂ UNSM), Feb. 1909 (7♂♂, 3♀♀ UNSM), Sept. 1909 J. T. Zimmer (1♀ UNSM); Lincoln, May 1924 (1♀ UNSM); Lincoln, Oct. 1932 (1♀ UNSM), Dec. 1932 J. C. Gollehon (1♀ UNSM). **Douglas Co.:** Omaha, Oct. 1923 Owen Bryant (1♀ UNSM).

Remarks: This species was formerly in the genus *Hymenarcys.* Thomas (2012) created a genus *Mcphersonarcys* to accommodate this species. It is currently the only member of this genus. McPherson (1988) gave the distribution as Arkansas, Colorado, District of Columbia, Florida, Georgia, Iowa, Illinois, Indiana, Kansas, Kentucky, Massachusetts, Maryland, Michigan, Mississippi, Missouri, Montana, North Carolina, New Jersey, New York, Nebraska, Ohio, Oklahoma, Quebec, Saskatchewan, and Texas.

***Menecles insertus* (Say, 1832)**

Synonyms: *Pentatoma inserta* Say 1831: 6.

Menecles insertus Zimmer 1912: 13.

Specimens Examined: Gage Co.: Beatrice, April 1924 (1♂ UNSM). **Holt Co.:** June 1974 (2♀♀ UNSM). **Lancaster Co.:** Jan 1895 (1♂ UNSM); May 1913 L. M. Gates (1♂ UNSM); July 1908 J. T. Zimmer (1♀ UNSM). **Sarpy Co.:** Omaha, Child's point, Oct. 1923 Owen Bryant (1♀ UNSM).

Remarks: In this species, the body is ovoid and flattened, the head recedes into the pronotum and the anterolateral pronotal margins are convex. Froeschner (1988) gave the distribution of this species as Arizona, Arkansas, California, Connecticut, Illinois, Indiana, Kansas, Kentucky, Massachusetts, Michigan, Missouri, Montana, New Jersey, New York, Nebraska, Ohio, Ontario, Quebec, Pennsylvania, Rhode Island, and Utah. Rider (2012) and Koch et al. (2014) reported it for North Dakota and Minnesota, respectively.

Mormidea lugens (Fabricius, 1775)

Synonyms: *Pentatoma punctipes* Say 1825: 313.

Mormidea lugens Dallas 1851: 248.

Mormidea (*Melanochila*) *lugens* Zimmer 1912: 8.

Specimens Examined. Cherry Co.: June 1968 UNL Coll. Trip (1♀ UNSM). **Cuming Co.:** West Point, June 1888 (1♂ UNSM). **Lancaster Co.:** Lincoln, Sept. 1908 (1♀ UNSM), Feb. 1909 (2♂♂ UNSM), March 1910 J. T. Zimmer (2♀♀ UNSM); Roca, May 1911 Pool (1♀ UNSM); March 1921 (1♂ UNSM); May 1924 (1♀ UNSM); Oct. 1947 E. G. Burcham (1♂ UNSM); Aug. 2009 L. J. Meinke (1♀ UNL-ENTO). **Richardson Co.:** June 1976 (1♀ UNSM).

Remarks: This is the only species of this genus that has been reported from Nebraska. It can be distinguished from other members by the two white stripes on the pronotum. Zimmer (1912) recorded specimens from only the eastern part of the state, Lincoln and Roca in **Lancaster County** and West Point in **Cuming County.** It is widely distributed throughout the United States. In addition to the list provided by Froeschner (1988), it has been reported in Minnesota (Koch et al. 2014).

Oebalus pugnax (Fabricius, 1775)

Synonyms: *Cimex pugnax* Fabricius 1775: 704.

Oebalus pugnax Van Duzee 1904: 43.

Solubea pugnax Zimmer 1912: 8.

Specimens Examined: Lancaster Co.: March 1910 W. D. Rands & W. R. Martin (1♀ UNSM); March 1910 J. T. Zimmer (1♂ UNSM); Sept. 1933 (1♂ UNSM); (1♂, 1♀ UNSM); Lincoln, Sept. 2003 T. M. Jarecke (1♀ UNL-ENTO).

Remarks: This species and members of the genus *Mecidea* are the only narrow elongate Pentatomidae that occur in Nebraska. *Oebalus pugnax* can be distinguished by its anteriorly pointing humeral spines. Froeschner (1988) gave the distribution in the United States as Arizona, Arkansas, Colorado, Connecticut, District of Columbia, Florida, Georgia, Iowa, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, Minnesota, Mississippi, Missouri, Montana, North Carolina, New Jersey, New Mexico, New York, Nebraska, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia.

***Prionosoma podopioides* Uhler, 1863**

Synonyms: *Prionosoma podopioides* Uhler 1863: 364.

Prionosoma villosa Provancher 1888: 204.

Specimens Examined: Cheyenne Co.: Sidney, (1♂ UNSM). **Sheridan Co.:** Hay Springs, Aug. 1923 (1♂ UNSM). **Thomas Co.:** Halsey, Sept. 1958 R. Henzlik (1♀ UNSM).

Remarks: This is another pubescent species of Pentatomidae that occurs in Nebraska. It can be distinguished from *A. puberula* by the protruding tooth on each humeral angle and the tooth-like extensions on the corner of each abdominal segment. Its distribution in North America includes Arizona, Arkansas, British Columbia, California, Colorado, Iowa, Idaho, Illinois, Michigan, New Mexico, Nebraska, Nevada, Utah (Froeschner 1988), Kansas (Packauskas 2012), Missouri (Sites et al. 2012) and Minnesota (Koch et al. 2014).

***Trichopepla grossa* Van Duzee, 1918 [New State Record]**

Original Nomenclature: *Trichopepla grossa* Van Duzee 1918: 274.

Specimen Examined: Dawes Co.: War Bonnet Canyon June 1901 M. Cary (1? UNSM).

Remarks: This seems like a very rare species. Neither McPherson (1982) nor Froeschner (1988) reported it. The single specimen available from Nebraska has the tip of the abdomen broken off. However, there is a male specimen in the UNSM collection from Custer, **Custer Co.,** South Dakota. McDonald (1976) did a description of the genus *Trichopepla* in North America and provided the distribution of *T. grossa* as California, Idaho, South Dakota, Oregon, and Colorado.

***Trichopepla semivittata* (Say, 1832)**

Synonyms: *Pentatoma semivittata* Say 1831b: 9.

Trichopepla semivittata Zimmer 1912: 6.

Specimens Examined: Douglas Co.: Omaha, July 1913 L. T. Williams (1♂ UNSM). **Lancaster Co.:** Roca, May 1911 Pool (1♀ UNSM). **Merrick Co.:** Central City, July 1958 Atyeo & Anderson (1♀ UNSM).

Remarks: The distribution of this species in North America includes Arkansas, Colorado, District of Columbia, Delaware, Florida, Illinois, Indiana, Kansas, Louisiana, Michigan, Missouri, North Carolina, New Jersey, New York, Nebraska, Ohio, Ontario, Pennsylvania, Quebec, Texas, and Virginia (Froeschner 1988). See McDonald (1976) for description.

TRIBE HALYINI

Lariviere (1992) redescribed the genus *Brochymena*. He provided justifications to transfer some of the species originally described under *Brochymena* into a new genus, *Parabrochymena.* His finding was supported by Ahmad and McPherson (1998) and McPherson and Ahmad (2007) who distinguished between the two genera based on the structure of the male genitalia. They also proposed the tribe Hyalini for members of this genera occurring in the New World.

Brochymena cariosa **Stål, 1872 [New State Record]**

Original Nomenclature: *Brochymena cariosa* Stål 1872: 17.

Remark: McPherson (1982) and Froeschner (1988) listed it as occurring in Nebraska but there are no specimens in the collections to corroborate this. Neither was it reported by Zimmer (1912).

Brochymena sulcata **Van Duzee, 1918 [New State Record]**

Original Nomenclature: *Brochymena sulcata* Van Duzee 1918: 276.

Specimen Examined: Keith Co.: Aug. 1987 B. C. Ratcliffe (1♀ UNSM).

Brochymena quadripustulata (Fabricius, 1775)

Synonyms: *Cimex 4. pustulatus* Fabricius 1775: 704.

Brochymena quadripustulata Stål 1872: 16.

Specimens Examined: Adams Co.: Nov. 1981 Threckmorton (1♀ UNSM); Sept. 1983 N. Hamm (1♂, 1♀ UNSM); May 1985 B. Adrian (1♀ UNSM); Sept 1989 M. Tharp (1♂, 1♀ UNSM). **Banner Co.:** June 2019 B. Thomas (1♂). **Cass Co.:** Sept. 1914 L. M. Gates (1♀ UNSM). **Cherry Co.:** Sept. 1981 J. Creech (1♂ UNSM). **Clay Co.:** June 1932 (1♀ UNSM). **Cuming Co.:** May 1887 (1♂ UNSM); Sept. 1921 (1♀ UNSM); May 1926 (1♂ UNSM). **Hall Co.:** Sept. 1987 D. Clarke (1♂, 1♀ UNSM); Oct. 1987 D. Clarke (1♀ UNSM); Sept. 1981 L. Hansen (1♂ UNSM); April 1987 Tom Masgrave (1♂ UNSM). **Lancaster Co.:** Nov. 1898 R. H. Wolcott (1♂ UNSM); May 1908 (1♀ UNSM); Malcolm, May 1909 (2♀♀ UNSM); Feb 1911 (1♀, 1♂ UNSM), Sept. 1911 J. T. Zimmer (1♂ UNSM); July 1913 L. T. Williams (1♂ UNSM); March 1924 (1♀ UNSM); May 1929 Fred V. Gray (1♂ UNSM); Oct. 1931 J. C. Gollehon (1♀ UNSM); April 1932 Allington (1♂ UNSM); Sept. 1932 Mason (1♂ UNSM); Oct. 1932 (1? UNSM); July 1954 E. W. Hamilton (1♀ UNSM); Oct. 1983 J. M. McCoy (1♀ UNL-ENTO); April (1♀ UNSM); June (1♂ UNSM); Sept. (1♂ UNSM). **Nuckolls Co.:** Hartmon (1♂ UNSM). **Richardson Co.:** July 1915 E. M. Partridge (1♀ UNSM). **Sarpy Co.:** Omaha, Child's Point, Sept. 1913 E. M. Partridge (1♀ UNSM); Omaha, Child's Point, June 1913 L. T. Williams (1♀ UNSM); Omaha, Child's Point, Oct. 1923 Owen Bryant (1♂, 1♀ UNSM); Omaha, Child's Point, Aug. 1937 E. C. Klostermeyer (1♀ UNSM). **Saunders Co.:** (1♂ UNSM). **Sioux Co.:** July 1911 R. W. Dawson (1♀ UNSM); July 1912 L. T. Williams (2♂♂ UNSM); June 1915 L. M. Gates (1♀ UNSM); Aug. 1963 R. E. White (1♂ UNSM); (2♂♂, 1♀ UNSM).

***Parabrochymena arborea* (Say, 1825)**

Synonyms: *Pentatoma arborea* Say 1825: 311.

Brochymena arborea Van Duzee 1904: 27.

Specimens Examined. Antelope Co.: Neligh, Aug. 1908 W. C. Thompson (1♂ UNSM). **Cass Co.:** Weeping Water, Sept. 1909 J. T. Zimmer (1♀ UNSM); South Bend, June 1915 E. G. Anderson (1♀ UNL-ENTO). **Douglas Co.:** Omaha, July 1913 L. T. Williams (3♀♀ UNSM). **Johnson Co.:** Sept. 1979 J. Pickerill (1♀ UNL-ENTO). **Lancaster Co.:** Aug. 1911 R. W. Dawson (1♂ UNSM); Aug. 2004 E. Reike (1♀ UNL-ENTO); Sept. (1♂ UNSM); Aug. (1♀ UNSM); May (1♀ UNSM). **Sioux Co.:** (1♀ UNSM).

TRIBE MECIDEINI

***Mecidea major* Sailer, 1952 [New State Record]**

Synonyms: *Mecidea longula* Uhler 1876: 283.

Mecidea major Sailer 1952: 478.

Specimens Examined. Clay Co.: South Central Ag. Lab., Clay Center, Aug. 2017 B. Ademokoya (1♀). **Lancaster Co.:** July 1934 (1♀ UNSM); Sept. 1934 (1♀ UNSM); Lincoln, Sept. 2001, S. C. Becker (1♀ UNL-ENTO); Spring Creek Prairie, Aug. 2006 L. Toda (1♂ UNL-ENTO); Lincoln, UNL East Campus, Aug. 2006, S. A. Palizada (1♀ UNL-ENTO); Sept. 2016 V. Petersen (1♂ UNL-ENTO). **Pawnee Co.:** Pawnee Prairie, Aug. 2012, G. Cooper (1♀ UNL-ENTO). **Saunders Co.:** ENREC, Ithaca, June. 2018 (1♂), July. 2018 B. Ademokoya (1♀).

TRIBE NEZARINI

Chinavia hilaris (Say, 1832)

Synonyms: *Pentatoma hilaris* Say 1832: 9.

Nezara hilaris Zimmer 1912: 15.

Acrosternum hilare Parshley 1915: 175.

Acrosternum (*Chinavia*) *hilare* Rolston 1983: 155.

Specimens Examined. Adams Co.: Sept. 1985 G. Mueller (1? UNSM). **Buffalo Co.:** July 2006 M. L. Brust (1♂ UNL-ENTO). **Clay Co.:** July 2019 (10♂♂) (4♀♀), Aug. 2019 B. Ademokoya (1♂) (3♀♀). **Cuming Co.:** West Point, Sept. 1921 (1♂ UNSM). **Douglas Co.:** Omaha, Aug 1913 L. T. Williams (1♀ UNSM). **Jefferson Co.:** June 1991 C. A. Springer (2♀♀ UNSM). **Lancaster Co.:** Roca, April 1909 R. H. Wolcott (1♀ UNSM); July 1910 L. Bruner (1♂ UNSM); June 1933 D. B. Whelan (1♂ UNSM); Lincoln Aug. 1993 B. Kalisch (1♂ UNL-ENTO); Sept. 2004 E. Reike (1♀ UNL-ENTO); Aug. 2010 F. Mustafa (1♀ UNL-ENTO); May 2013 Ivy M Orellana (1♀ UNL-ENTO), Lincoln Oct. 2011 J. C. Alouw (1♀ UNL-UNSM), Lincoln UNL East Campus July 2015 E. A. Knoell (1♀ UNL-UNSM). **Nemaha Co.:** Indian Cave State Park, Sept. 2011 C. F. de Oliveira (1♀ UNL-ENTO); Indian Cave State Park, June 2013 G. Cooper (1♂ UNL-ENTO); Aug. 2013 S. Ramirez II; Lincoln, May 2013 Ivy M Orellana (1♀ UNL-ENTO); Aug. 2021 B. Ademokoya (1♂) (3♀♀). **Platte Co.:** Columbus May 1957 E. A. Froemel **Richardson Co.:** July 1976 (2♂♂ UNSM) (3♀♀ UNSM); July 1982 A. Reifschneider (2♂♂ UNSM) (1♀ UNSM); May 1990 C. A. Springer (1♂ UNSM) (1♀ UNSM); June 2021 B. Ademokoya (2♂♂) (3♀♀). **Saunders Co.:** May 2018 (2♂♂) (4♀♀), June 2018 (10♂♂)

(10♀♀), July 2018 (11♂♂) (7♀♀), May 2019 (1♂), June 2019 (5♂♂) (8♀♀), July 2019 E. Knoell (10♂♂) (10♀♀). **Washington Co.:** Blair, Aug. 1930 C. Gollehon (1♂ UNSM).

Remarks: This species was described under Tribe Pentatomini by McPherson (1982) and Froeschner (1988).

Chlorochroa belfragii (Stål, 1872)

Synonyms: *Pentatoma* (*Rhytidolomia*) *Belfragei*: Van Duzee 1904: 37.

Liodermion (*Rhytidolomia*) *belfragii*: Zimmer 1912: 7.

Rhytidolomia belfragii McPherson 1982: 52.

Chlorochroa (*Rhytidilomia*) *belfragii* Thomas 1983: 221.

Remarks: There is no specimen available for examination. However, there are multiple reports of this species in Nebraska. Apart from Uhler (1876), Zimmer (1912) reported a male specimen from West Point, **Cuming Co.** Oct. 1888 by L. Bruner while Wheeler (2015) reported this species and *C. faceta* from the saline wetlands of eastern Nebraska.

Chlorochroa faceta (Say, 1825)

Synonyms: *Pentatoma faceta* Say 1825: 315.

Pentatoma (*Rhytidolomia*) *faceta*: Van Duzee 1904: 38

Liodermion (*Rhytidolomia*) *faceta*: Zimmer 1912: 7

Specimens Examined. Lancaster Co.: July (1♂ UNSM); Feb. 1895 (1♀ UNSM); Sept. 1895 (1♀ UNSM); March 1911 (1♀ UNSM); March (1♂ UNSM); April (1♂ UNSM) (1♀ UNSM); Aug. (1♂ UNSM); July 1908 J. T. Zimmer (1♀ UNSM); Oct. 1894 (1♂ UNSM) (1♀ UNSM); Feb 1927 R. H. Wolcott (1♀ UNSM) (2♂♂ UNSM); Sept. 1937 (1♀

UNSM); Oct. 1947 E. G. Burcham (1♂ UNSM) (1♀ UNSM); April 1915 E. M. Partridge (1♀ UNSM); Aug. 1916 M. H. Swenk (1♂ UNSM).

Remarks: This species was recently reported from Nebraska by Wheeler (2015)

Chlorochroa ligata **(Say, 1831) [New State Record]**

Synonyms: *Pentatoma faceta* Say 1825: 5.

Pentatoma (*Chlorochroa*) *ligata*: Van Duzee 1904: 41.

Rhytidolomia (*Chlorochroa*) *ligata*: Kirkaldy 1909: 53.

Specimens Examined. Chase Co.: July 1954 E. W. Hamilton (1♀ UNSM). **Cherry Co.:** Aug. 2003 L. J. Meinke (1♀ UNL-ENTO). **Dawes Co.:** June 1910 (1♀ UNSM), July 1910 L. Bruner (9♂♂ UNSM) (10♀♀ UNSM); Sept. 1910 (1♀ UNSM); Sept. 1911 J. T. Zimmer (1♂ UNSM). **Garden Co.:** July 1984 K. Bohlim (1♀ UNSM). **Keith Co.:** July 1954 E. W. Hamilton (1♀ UNSM). **Morrill Co.:** June 2019 B. Thomas (8♂♂) (5♀♀); **Red Willow Co.:** May (1♂ UNSM). **Sioux Co.:** Aug 1912 R. W. Dawson (1♂ UNSM).

Remarks: This species has different color forms. It is Black in the south, green in the north and purplish green in intermediate zones. All the samples collected during the recent survey are purplish green.

Chlorochroa persimilis **Horvath, 1908 [New State Record]**

Synonyms: *Pentatoma* (*Chlorochroa*) *juniperina* Van Duzee 1904: 39.

Chlorochroa persimilis: Horvath 1908: 555.

Specimens Examined: Cherry Co.: June R. H. Wolcott (3♀♀ UNSM). **Gage Co.:** Aug. 1911 A. G. Vestal (1♀ UNSM). **Lancaster Co.:** Lincoln Sept. 2018 L. J. Meinke (2♀♀). **Sioux Co.:** NE July 1971 (3♀♀ UNSM).

Remarks: It is difficult to separate the females of this species from the green form of *C. ligata* due to the very close resemblance. Males are easily distinguished from the structure of the genitalia. The specimens from Lancaster Co. were assigned to *C. persimilis* based on occurrence data for the color form of *C. ligata* and the absence of a mottled ivory appearance.

***Chlorochroa sayi* (Stål, 1872) [New State Record]**

Synonyms: *Pentatoma* (*Chlorochroa*) *Sayi* Van Duzee 1904: 41.

Rhytidolomia (*Chlorochroa*) *sayi* Kirkaldy 1909: 54.

Specimens Examined. Cheyenne Co.: June 2019 B. Thomas (1♂). **Kimball Co.:** Aug. 1930 D. B. Whelan (2♀♀ UNSM); Aug. 1915 E. M. Partridge (1♂ UNSM). **Morrill Co.:** June 2019 B. Thomas (1♀). **Scotts Bluff Co.:** Mitchell June 1998 (1♂ UNL-ENTO); Mitchell research station June 1998 J. Thomas and G. Hein (2♂♂ UNL-ENTO) (1♀ UNSM); Scotts Bluff July 1998 (1♂ UNL-ENTO); Mitchel, PHREC Ag Lab July 2019 J. D. Cluever (5♂♂) (6♀♀). **Sioux Co.:** July 1914 (1♂ UNSM) (1♀ UNSM); July 1915 (1♀ UNSM); June 1915 L. M. Gates (1♂ UNSM); July 1947(1♂ UNSM).

***Chlorochroa uhleri* Stål 1872**

Synonyms: *Pentatoma* (*Chlorochroa*) *Uhleri* [sic] Van Duzee 1904: 39.

Rhytidolomia (*Chlorochroa*) *uhleri* Kirkaldy 1909: 54.

Liodermion (*Chlorochroa*) *uhleri* Zimmer 1912: 7.

Specimens Examined. Boyd Co.: June 1933 D. B. Whelan (2♀♀ UNSM). **Chase Co.:** July 1954 E. W. Hamilton (1♀ UNSM); May 1961 Crew (1♀ UNSM). **Kimball Co.:** Aug. 1930 D. B. Whelan (1♂ UNSM) (5♀♀ UNSM). **Morrill Co.:** July 1940 R. E. Hill (1♂ UNSM) (1♀ UNSM). **Southeast NE** (1♀ UNSM). **Scotts Bluff Co.:** Aug. 1935 D. B Whelan (1♀ UNSM); July 1940 R. E. Hill (2♂♂ UNSM) (4♀♀ UNSM); Aug. 1954 L. W. Anderson (1♀ UNSM).

Chlorochroa viridicata **(Walker, 1867)**

Synonyms: *Pentatoma* (*Lioderma*) *viridicata* Van Duzee 1904: 39.

Rhytidolomia (*Liodermion*) *viridicata* Kirkaldy 1909: 53.

Liodermion (*Liodermion*) *viridicata* Zimmer 1912: 7.

Specimens Examined: Saline Co.: (1♂ UNSM). **Scotts Bluff Co.:** July 1914 L. M. Gates (1♂ UNSM). There is a third specimen labeled "**Western NE** (1♂ UNSM)", with no date and collector information.

Remarks: Recent survey of Nebraska Sand Hills reported this species (Wheeler 2018).

TRIBE PENTATOMINI

Banasa calva **(Say, 1832) [New State Record]**

Synonyms: *Pentatoma calva* Say 1832: 318.

Banasa calva Van Duzee 1904: 59.

Specimens Examined: Boone Co.: July 1977 E. G. Riley (2♂♂ UNSM) (1♀ UNSM). **Lancaster Co.:** Lincoln, Sept. 2002 J. D. Carstens (1♂ UNL-ENTO); Lincoln, July 2004

C. Hobson (1♀ UNL-ENTO). **Nehama Co.:** Indian Cave State Park, Aug. 2013 S. M. Spomer (1♀ UNL-ENTO). **Platte Co.:** June 1996 B. C. Ratcliffe & M. L. Jameson (1♀ UNSM). **Randolph Co.:** April 1976 E. G. Riley (3♂♂ UNSM) (1♀ UNSM). **Richardson Co.:** June 1976 (2♂♂ UNSM) (2♀♀ UNSM); June 1982 (2♂♂ UNSM) (2♀♀ UNSM); July 1982 A. Reifschneider) (2♂♂ UNSM); Aug. 2021 B. Ademokoya (2♀♀).

***Banasa dimidiata* (Say, 1832)**

Synonyms: *Pentatoma dimiata* [sic] Say 1832: 7.

Nezara (*Banasa*) *dimiata* [sic] Kirkaldy 1909: 122.

Banasa dimidiata Zimmer 1912: 16.

Specimens Examined. Cass Co.: 5 km E Greenwood, Sept. 2020 K. Koch (1♀). **Cuming Co.:** (1♂ UNSM) (1♀ UNSM); Sept. 1887 (1♀ UNSM), Sept. 1921 (1♂ UNSM). **Dawes Co.:** July (1♀ UNSM). **Holt Co.:** July 19874 (1♂ UNSM) (1♀ UNSM). **Keya Paha Co.:** June 1902 W. D. Dawson (1♀ UNSM). **Lancaster Co.:** March (1♀ UNSM). **Platte Co.:** June 1996 B. C. Ratcliffe & M. L. Jameson (1♀ UNSM). **Rock Co.:** Aug. 1902 W. D. Pierce (1♂ UNSM) (1♀ UNSM). **Saunders Co.:** July 2018 E. Knoell (2♀♀); 3.5 km E Ithaca. Sept. 2020 K. Koch (1♀); **Sioux Co.:** (1♂ UNSM), Aug. 1908 E. W. Dawson (1♀ UNSM).

***Banasa euchlora* Stål, 1872 [New State Record]**

Synonyms: *Banasa euchlora* Stål 1872: 44.

Nezara (*Atomosira*) *euchlora* Kirkaldy 1909: 123.

Specimens Examined. Lancaster Co.: July 1976 M. A. Schmidt (1♀ UNSM). **Lancaster Co.:** Lincoln Sept. 2006 K. Korus (1♀ UNL-ENTO).

Banasa sordida (Uhler, 1871) [New State Record]

Synonyms: *Atomosira sordida* Uhler 1871: 98.

Banasa sordida Stål 1872: 44.

Nezara (*Atomosira*) *sordida* Kirkaldy 1909: 123.

Specimens Examined. Cherry Co.: July 1977 (2♀♀ UNSM). **Knox Co.:** Aug. 2001 L. J. Meinke (1♂ UNL-ENTO). **Richardson Co.:** July 1982 A. Reifschneider (1♀ UNSM). **Saunders Co.:** July 2019 E. Knoell (1♀).

Tepa rugulosa (Say, 1831)

Synonyms: *Pentatoma rugulosa* Say 1832: 7.

Thyanta rugulosa Van Duzee 1904: 54.

Thyanta punctiventris Van Duzee 1904: 55.

Thyanta punctiventris Zimmer 1912: 15.

Specimens Examined. Cass Co.: 5 km E Greenwood, Oct.2020 K. Koch (2♀♀). **Hayes Co.:** June 1941 (1♂ UNSM); **Lancaster Co.:** April (1♀ UNSM); **Sioux Co.:** (1♀ UNSM). **Saunders Co.:** ENREC Ithaca, June 2018 E. Knoell (1♂) (1♀); 6 km W Memphis, Oct.2020 K. Koch (1♀).

Remarks: Rolston and McDonald (1984) separated this genus from *Thyanta* while Rider (1986) synonymized *T. punctiventris* and *T. rugulosa.*

Tepa vanduzeei **Rider, 1986 [New State Record]**

Synonyms: *Tepa punctiventris* Rolston and McDonald 1984: 78

Tepa vanduzeei Rider 1986: 555.

Specimens Examined. Hayes Co.: Hayes center June 1941 (2♂♂ UNSM) (4♂♂ UNSM). **Lancaster Co.:** Lincoln March (1♂ UNSM). **Sioux Co.:** West Point July 1915 L. M. Gates (1♀ UNSM).

Thyanta calceata **(Say, 1831) [New State Record]**

Synonyms: *Thyanta calceata* Blatchley 1926: 117.

Pentatoma calceata Say 1832: 8.

Specimens Examined. Banner Co.: Sept. 1983 (2♂♂ UNL-ENTO). **Clay Co.:** Sept. 1989 M. Tharp (1♀ UNSM. **Lancaster Co.:** Davey Sept. 2003 K. E. Jeffries (1♂ UNL-ENTO).

Thyanta custator accerra **McAtee, 1919**

Thyanta custator var. *accerra* McAtee 1919: 16.

Thyanta acerra Blatchley 1926: 118.

Specimens Examined. Banner Co.: Sept. 1983 (2♂♂ UNL-ENTO). **Blaine Co.:** July 1996 K & C Messenger (1♀ UNSM). **Boyd Co.:** Butte, July 1914 R. W. Dawson (1♂ UNSM). **Cass Co.:** Weeping Water, Sept. 1909 J. T. Zimmer (2♀♀ UNSM); Louisville, Aug. 1914 H. A. Jones (1♀ UNSM); Louisville, July 1914 E. G. Anderson (1♂ UNSM) (1♀ UNSM) **Chase Co.:** Imperial, July 1911 J. T. Zimmer (1♀ UNSM), Imperial, June 1913 R. W. Dawson (3♀♀ UNSM); July 1961 Crew (1♀ UNSM); Imperial, Sept. 1961 W. T. Atyeo & S. H. Valder (2♀♀ UNSM); Imperial, Sept. 1961 Stokes and Valder (1♀

UNSM); Aug. 1996 K & C Messenger (1♀ UNSM). **Cherry Co.:** June 1968 UNL Coll. Trip (1♂ UNSM); July 1977 (1♀ UNSM); June 2019 B. Thomas (1♀). **Cheyenne Co.:** June 2019 B. Thomas (2♂♂) (2♀♀). **Clay Co.:** Sept 1989 M. Tharp (1♂ UNSM) (1♀ UNSM); South Central Ag. Lab, Clay center Aug. 2017 (7♂♂) (4♀♀), June 2019 B. Ademokoya (1♂) (4♀♀); July 2018 T. Omtvedt (2♂♂) (4♀♀). **Colfax Co.:** July 2001 L. J. Meinke (1♀ UNL-ENTO). **Custer Co.:** Aug. 1970 (4♀♀ UNSM). **Dakota Co.:** Aug. 1912 L. T. Williams (1♂ UNSM) (2♀♀ UNSM). **Dawes Co.:** Pine Ridge, July (1♂ UNSM); Toadstool State Park, Aug. 1963 D. W. Ribble (1♀ UNSM). **Dixon Co.:** July 2017 (1♂) (3♀♀), Aug. 2017 (2♂♂) (3♀♀), June 2019 B. Ademokoya (3♀♀). **Douglas Co.:** Omaha, June 1913 L. T. Williams (1♀ UNSM). **Dundy Co.:** Haigler, July 1911 J. T. Zimmer (1♂ UNSM); Haigler, Aug. 1909 C. H. Gable (3♀♀ UNSM). **Fillmore Co.:** Fairmont, July 1914 G. W. Deming (1♂ UNSM). **Grant Co.:** Hyannis, Sept. 1961 S. Valder (1♂ UNSM); Hyannis, Sept. 1961 G. Stokes (1♀ UNSM); June 2019 B. Thomas (1♂) (2♀♀). **Hall Co.:** Grand Island, June 1958 W. T. Atyeo (1♂ UNSM) (4♀♀ UNSM). Sept. 1989 M. Tharp (1♂ UNSM) (2♀♀ UNSM). **Holt Co.:** Atkinson, Sept. 1960 (1♂ UNSM) (2♀♀ UNSM). **Jefferson Co.:** Fairbury, Aug. 1914 L. M. Gates (1♀ UNSM). **Keith Co.:** Ogallala June 1913 R. W. Dawson (1 ♀ UNSM), Cedar point Biological Station July 2010 R. F. Berger (1♀ UNL-ENTO). **Keya Paha Co.:** Carns, June 1902 W. D. Pierce (1♀ UNSM). **Kimball Co.:** June 2019 B. Thomas (3♀♀). **Lancaster Co.:** Lincoln, July 1889 (1♀ UNSM), July 1908 (1♀ UNSM), Lincoln, March 1909 J. T. Zimmer (1♂ UNSM) (1♀ UNSM); Sept. 1909 (1♂ UNSM) (2♀♀ UNSM), Oct. 1909 (5♀♀ UNSM), March 1910 (1♂ UNSM) (1♀ UNSM); Sept. 1909 E. W. Dawson (1♂ UNSM) (1♀ UNSM); Sept. 1910 (1♀ UNSM), Oct. 1912 L. Bruner (1♂ UNSM) (1♀ UNSM); June 1911 L. M. Gates

(2♂♂ UNSM); June 1913 (1♂ UNSM) (1♀ UNSM); Lincoln, June 1913 W. Deming (1♀ UNSM); Lincoln, June 1913 L. M. Gates (1♀ UNSM), June 1914 G. W. Deming (2♀♀ UNSM); July 1914 E. M. Partridge (1♀ UNSM); May 1925 Fred Sundeen (1♀ UNSM); Sept. 1930 Enders (1♀ UNSM); Oct. 1931 (2♂♂ UNSM); Aug. 1932 Hill (1♀ UNSM); Oct. 1932 J. C. Gollehon (1♀ UNSM); Oct. 1932 (1♂ UNSM) (3♀♀ UNSM); July 1933 Vance (1♀ UNSM); July 1935 D. B. Whelan (2♂♂ UNSM) (1♀ UNSM); Aug. 1935 Darlington (1♀ UNSM); Oct. 1947 E. G. Burcham (1♂ UNSM); Sept. (2♂♂ UNSM); Sept. 1952 W. Stevens (2♀♀ UNSM); Sept. 1952 M. Bomberger (1♀ UNSM); July 1954 B. W. Alpuerto (1♂ UNSM); Sept. 1956 D. L. Silhacek (2♀♀ UNSM); Oct. 1956 S. D. Carlson (8♂♂ UNSM) (8♀♀ UNSM); May 1980 (1♂ UNSM); July 1990 B. C. Ratcliffe (1♂ UNSM); Pioneers Park July 2004 E. Reike (1♂ UNL-ENTO); Lincoln Aug. 2004 C. Roberts (1♀ UNL-ENTO); ENREC Ithaca July 2019 R. Stacke (1♀); Lincoln, UNL East Campus, Oct. 2020 K. Koch (1♂). **Lincoln Co.:** North Platte, July 1912 L. M. Gates (1♀ UNSM); Sutherland, Aug. 1947 E. G. Burcham (1♀ UNSM); Sutherland, Aug. 1947 E. G. Burcham (1♀ UNSM. **Merrick Co.:** Archer, Aug. 1935 D. E. Eckhoff (2♀♀ UNSM). **Morrill Co.:** Bridgeport, July 1940 R. E. Hill (1♂ UNSM) (1♀ UNSM). **Nuckolls Co.:** July 1989 D. Ely (1♀ UNSM). **Otoe Co.:** Syracuse, Magoy (1♀ UNSM); Syracuse, Sept. 1932 C. F. Masters (1♀ UNSM); Nebraska City, July 1955 (1♂ UNSM). **Sarpy Co.:** Camp Gifford, July 1937 E. C. Klostermeyer (1? UNSM); Aug. 2002 A. L. Kizzier (2♂♂ UNL-ENTO). **Saunders Co.:** Cedar Bluffs, Sept. 1913 G. W. Deming (1♀ UNSM); July 2017 (2♀♀), Aug. 2017 (3♂♂) (6♀♀), Sept. 2017 (12♂♂) (8♀♀), June 2018 (2♀♀), Aug. 2018 B. Ademokoya (4♀♀); June 2018 (1♂) (3♀♀), July 2018 (3♂♂), Aug. 2018 (1♂) (1♀), July 2019 E. Knoell (2♂♂); 3.5 km E Ithaca, Oct. 2020 K. Koch (1♂) (1♀). **Scott Bluff**

Co.: Mitchell, July 1912 (2♀♀ UNSM), July 1913 (2♀♀ UNSM), July 1914 (2♂♂ UNSM), June 1915 (2♂♂ UNSM) (2♀♀ UNSM), July 1915 L. M. Gates (3♂♂ UNSM) (7♀♀ UNSM); Aug. 1947 (1♂ UNSM); Aug. 1954 L. W. Anderson (1♂ UNSM) (2♀♀ UNSM); Mitchell, Aug. 1955 L. W. Quate (1♀ UNSM); Aug. 1959 W. T. Atyeo (1♀ UNSM); Mitchell PHREC Ag Lab July 2019 (1♂), Aug. 2019 (3♂♂) (4♀♀), Aug. 2019 Gering Hwy NE 91 (1♂), Scottsbluff, PHREC July 2021 (1♂) (2♀♀), Aug. 2021 J. D. Cluever (1♀) . **Sheridan Co.:** June 2019 B. Thomas (1 ♂). **Sioux Co.:** July 1910 J. T. Zimmer (3♀♀ UNSM); June 1911 R. W. Dawson (1♂ UNSM) (2♀♀ UNSM); July 1912 L. T. Williams (1♂ UNSM); **Thomas Co.:** Halsey, July 1912 J. T. Zimmer (1♀ UNSM); Halsey, Aug. 1920 C. B. Philip (1♀ UNSM); Halsey, Aug. 1923 L. G. Worley (1♂ UNSM). Halsey, Aug. 1957 (2♀♀ UNSM), Aug. 1958 R. Henzlik (2♀♀ UNSM). **Webster Co.:** Red Cloud, Aug. 1910 J. T. Zimmer (1♂ UNSM); Red Cloud, June 1913 R. W. Dawson (1♂ UNSM) (4♀♀ UNSM).

Thyanta custator custator **(Fabricius, 1803)**

Synonyms: *Cimex custator* Fabricius 1803: 164.

Pentatoma custator Dallas 1851: 251.

Thyanta custator Stål 1860: 58.

Specimens Examined. Banner Co: Sept. 1983. **Cass Co.** Louisville, July 1914 E. G. Anderson (1♂ UNSM). **Custer Co.:** Aug. 1970 (1♀ UNSM) **Lancaster Co.:** June 1911 J. T. Zimmer (1♂ UNSM), Oct. 1932 J. C. Gollehon (1♂ UNSM), Sept. 1952 O. J. Webster (1? UNSM); Oct. 1956 S. D. Carlson (1♀ UNSM). **Saunders Co.:** 9.5 km S Fremont, Sept. 2020 K. Koch (1♀).

Thyanta pallidovirens **(Stål, 1859) [New State Record]**

Synonyms: *Pentatoma pallido-virens* [sic] Stål 1859: 227.

Thyanta pallido-virens [sic] Van Duzee 1904: 53.

Specimens Examined. Boyd Co.: Butte, July 1914 R. W. Dawson (1♀ UNSM). **Cass Co.:** 5 km E Greenwood, Oct. 2020 K. Koch (2♀♀) (1♂). **Dixon Co.:** Haskell Ag. Lab, Aug. 2017 B. Ademokoya (1♀). **Douglas Co.:** Omaha, June 1913 L. T. Williams (2♂♂ UNSM). **Hall Co.:** Grand Island, June 1958 (1♂ UNSM). **Kimball Co.:** June 2019 B. Thomas (1♀). **Lancaster Co.:** Lincoln, Oct. 1909 J. T. Zimmer (1♂ UNSM); Malcolm, Sept. 1909 C. B. Oertel (1♂ UNSM) (1♀ UNSM); Lincoln June 1913 G. W. Deming (1♀ UNSM) (1♂ UNSM), Lincoln Oct. 1932 J. C. Gollehon (1♂ UNSM), Lincoln July 1934 (4 ♀♀ UNSM), Aug. 1934 (1♀ UNSM), **Merrick Co.:** Archer, Aug. 1935 D. E. Eckhoff (1♀ UNSM). **Scotts Bluff Co.:** Mitchell, July 1915 L. M. Gates (2♂♂ UNSM); Mitchell PHREC Ag Lab June 2019 J. D. Cluever (1♂), July 2019 (1♂), July 2021 (♀). **Sioux Co.:** Glen, Aug. 1905 (1♀ UNSM); Monroe Canyon, June 1911 R. W. Dawson (1♀ UNSM); Wood reserve Ft. Robinson Aug. 1959 UNL Museum Entomology Expedition (1♀ UNSM). **Thomas Co.:** Halsey, Aug. 1920 C. B. Philip (1♂ UNSM).

Thyanta perditor **Fabricius, 1794**

Synonyms: *Cimex perditor* Fabricius 1794: 102.

Thyanta perditor Van Duzee 1904: 53.

Remarks: This species is more southern in distribution. There is no specimen available for examination. However, Uhler (1876) reported it from Nebraska.

TRIBE PROCLETICINI

Dendrocoris humeralis **(Uhler, 1877) [New State Record]**

Synonyms: *Dendrocoris humeralis* Bergroth 1891: 228.

Liotropis humeralis Van Duzee 1904: 62

Specimens Examined. Cass Co.: South Bend. June 1915 E. G. Anderson (1♀ UNSM). **Douglas Co.:** Omaha, July 1913 (1♂ UNSM), Aug. 1914 L. T. Williams (1♂ UNSM) (1♀ UNSM).

TRIBE STRACHIINI

Murgantia histrionica **(Hahn, 1834)**

Synonyms: *Strachia histrionica* Hahn 1834: 116.

Murgantia histrionica Zimmer 1912: 15.

Specimens Examined. Adams Co.: Oct. 1989 C. A. Springer (2♂♂ UNSM) (5♀♀ UNSM); Sept. 1989 A. Diaz (3♂♂ UNSM) (2♀♀ UNSM). **Boone Co.:** Aug. 1977 E. G. Riley (1♀ UNSM). **Brown Co.:** Johnstown, July 1920 L. E. Wontz (3♂♂ UNSM); Ainsworth, July 1920 E. J. Haice, on Cabbage (1♂ UNL-ENTO). **Buffalo Co.:** Aug. 1965 L. W. Quate (1♀ UNSM). **Cass Co.:** 5 km E Greenwood, Sept. 2020 K. Koch (1♂). **Chase Co.:** Imperial, June 1913 R. W. Dawson (1♂ UNSM); July 1954 E. W. Hamilton (3♂♂ UNSM) (5♀♀ UNSM); Imperial, May 1961 Crew (1♀ UNSM). **Clay Co.:** Clay Center, July 1920 T. Gardner (1♀ UNSM); Clay Center, July 1920 J. H. Cloydough (1♀ UNL-ENTO); Sept. 1991 N. Fernendez (3♂♂ UNSM) (1♀ UNSM); Clay Center, Sept. 1991 A. Nehls (5♂♂ UNSM) (1♀ UNSM); South Central Ag. Lab, Clay Center, July 2017 B. Ademokoya (1♂) (1♀), Aug. 2018 B. Ademokoya (1♂). **Cuming Co.:** West Point, Aug.

2005 J. D. Ritter (1♀ UNL-ENTO). C**uster Co.:** Aug. 1970 T. Gardner (3♂♂ UNSM) (5♀♀ UNSM). **Dawson Co.:** Overton, July 1920 Mary L. Wilson (1♂ UNSM). **Dixon Co.:** Aug. 2017 B. Ademokoya (1♂) (2♀♀). **Fillmore Co.:** Fairmont, Aug. 1913 G. W. Deming (1♀ UNSM). **Franklin Co.:** Upland, Aug. 1920 Ralph Lohr (1♀ UNSM). **Frontier Co.:** Stockville, June 1920 W. M. Campbell (1♂ UNSM). **Garden Co.:** Lewellen, July 1920 L. A. Marshall (1? UNSM); Aug. 1955 L. W. Quate (1♂ UNSM); Oshkosh, July 1920 H. A. Mopk (1♀ UNSM). **Hall Co.:** Grand Island, Sept. 1920 E. O. Roush (1♂ UNSM) (1♀ UNSM). **Harlan Co.:** Republican City, Aug. 1977 I. Miller (1♂ UNL-ENTO). **Holt Co.:** Stuart, July 1920 Mopt (1♂ UNSM). **Hooker Co.:** Mullen, June 1920 T. Pierce (1♀ UNSM). **Keith Co:** July 1985 (3♂♂ UNSM) (2♀♀ UNSM), July 1986 B. C. Ratcliffe (1♂ UNSM); July 1988 M. E. Jameson (4♂♂ UNSM) (4♀♀ UNSM). **Knox Co.:** July 1959 E. A. Froemel (2♀♀ UNSM). **Lancaster Co.:** Aug. 1913 J. T. Zimmer (4♂♂ UNSM) (4♀♀ UNSM), June 1914 G. W. Deming (2♀♀ UNSM); April 1932 Allington (1♀ UNSM); Lincoln, June 1985 (1♂ UNSM) (1♀ UNSM), Sept. 1985 (6♂♂ UNSM) (2♀♀ UNSM), Sept. 1987 (5♂♂UNSM) (5♀♀ UNSM), Oct. 1989 C. A. Springer (1♀ UNSM); Aug. 1992 B. Kalisch (1♂ UNL-ENTO) (1♀ UNL-ENTO); Lincoln, Sept. 2002 J. D. Carstens (1♂ UNL-ENTO); Lincoln, Sept. 2002 K. Y. Bontrager (1♀ UNL-ENTO); Lincoln, Sept. 2003 R. E. Denton (1♂ UNL-ENTO); Lincoln, Sept. 2003 P. D. Nelson (1♀ UNL-ENTO); Lincoln, Oct. 2003 D. Anderson (1♀ UNL-ENTO); Lincoln, Sept. 2003 T. M. Bryson (1♀ UNL-ENTO); Lincoln, July 2004 C. Hobson (2♀♀ UNL-ENTO); Lincoln, July 2004 J. R. Misar (1♀ UNL-ENTO); Lincoln, Aug. 2004 C. J. Borman (1♂ UNL-ENTO); Lincoln, Aug. 2004 C. Roberts (1♂ UNL-ENTO); Lincoln, Sept. 2004 M. L. Dipple (1♂ UNL-ENTO); Lincoln, Sept. 2004 J. L. Mohlman (1♀ UNL-

ENTO); Lincoln, Sept. 2004 C. M. Wasem (1♂ UNL-ENTO); Oct. 2004 U. Samarakoon (1♂ UNL-ENTO); Lincoln, Havelock, Oct. 2020 K. Koch (1♂). **Lincoln Co.:** Maxwell, June 1920 L. L. Zook (1♀ UNSM). **Saunders Co.:** June 1985 L. J. Meinke (1♂ UNL-ENTO) (1♀ UNL-ENTO); Aug. 2004 B. Tiroesele (1♂ UNL-ENTO); Lincoln, UNL East Campus, Sept. 2020 K. Koch (1♂). **Phelps Co.:** Holdrege, July 1920 J. L. Gilmore (1♂ UNSM) (1♀ UNSM). **Valley Co.:** North Loup, June 1920 John Cleary (1? UNSM), July 1956 J. A. Gregory (1♀ UNSM).

SUBFAMILY PODOPINAE Amyot and Serville, 1843

TRIBE PODOPINI

Amaurochrous brevitylus Barber and Sailer, 1953

Specimens Examined: Cuming Co.: West Point June 1888 (1♀ UNSM). **Lancaster Co.:** April 2004 L. Pierson (1♂ UNL-ENTO).

Remarks: Zimmer reported two male and three female specimens from West Point **(Cuming Co.),** Cedar Bluffs **(Saunders Co.)** and **Holt Co.** Barber and Sailer (1953) reported a specimen from the Sand Hills in Nebraska, collected in July by H. G. Barber.

Amaurochrous cinctipes (Say, 1828)

Synonyms: *Podops* (*Amaurochrous*) *cinctipes* Stål 1872: 15.

Podops cinctipes Van Duzee 1904: 22.

Amaurochrous cinctipes Zimmer 1912: 20.

Specimens Examined. Chase Co.: Imperial, Sept. 1961 Crew (1♀ UNSM), Sept. 1961 Stokes & Valder (1♂ UNSM). **Cuming Co.:** West Point, June 1884 (1♀ UNSM). **Gage**

Co.: Beatrice R. D. Goertzen Sept. 2003 (1♀UNL-ENTO). **Lancaster Co.:** March 1910 (1♂ UNSM), June 1908 J. T. Zimmer (1♀ UNSM); Oct. 1947 E. G. Burcham (1♀ UNSM); Sept. 2015 A. Hauver (1♂ UNL-ENTO). **Saunders Co.:** ENREC Ithaca, Sept. 2020 (2♂♂), Oct. 2020 K. Koch (1♀).

***Amaurochrous dubius* (Palisot de Beauvois, 1805) [New State Record]**

Synonyms: *Podops dubius* Van Duzee 1904: 77.

Podops peninsularis Blatchley 1926: 87.

Specimens Examined. Clay Co.: Sept. 1989 J. Hajny (1♀ UNSM); **Gage Co.:** Sept. 2003 R. D. Goertzen (1♀ UNL-ENTO). **Richardson Co.:** Indian Cave State Park July 1976 (1♀ UNSM).

Table 2.1. Pentatomidae species reported from the Midwest. (Note: Specimens from Nebraska include previously reported species and new state records).

Subfamily	Tribe	Scientific name
Predatory		
Asopinae *		*Alcaeorrhynchus grandis* (Dallas) [KS, MO, NE]
		Apateticus marginiventris (Stål) [NE]
		Apoecilus bracteatus (Fitch) [IN, IL, MI, MN, NE, OH, SD]
		Apoecilus cynicus (Say)[a] [IA, IL, IN, KS, MI, MN, MO, NE, ND, OH, WI]
		Conquistator mucronatus Uhler [IL]

		Euthyrhynchus floridanus (Linnaeus) [MO]
		Perillus bioculatus (Fabricius) [IA, IN, IL, KS, MI, MN, MO, ND, NE, OH]
		Perillus circumcinctus (Stål) [IA, IL, MI, MN, MO, ND, NE, SD]
		Perillus exaptus (Say)[a] [IL, IN, MI, MN, MO, ND, NE, OH]
		Perrilus lunatus knight [NE]
		Perillus strigipes (Herrich-Schäffer) [IL, IN, MI, MO, OH]
		Picromerus bidens (Linnaeus) [MI, OH]
		Podisus brevispinus (Dallas)[a] [IA, IL, IN, MI, MN, ND, NE, OH]
		Podisus maculiventris (Say) [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI]
		Podisus neglectus (Westwood) [IN, MI]
		Podisus placidus Uhler [IA, IL, MI, MN, MO, ND, NE, OH]
		Podisus serieventris Uhler [IL, IN, MI, MN, MO, ND, OH]
		Rhacognathus americanus Stål [MN, NE, MI, IN, IL, OH]
		Stiretrus anchorago (Fabricius) [IA, IL, IN, KS, MI, MN, MO, NE, OH]
		Tylospilus acutissimus (Stål) [KS, MO]
		Zicrona caerulea (Linnaeus) [KS, MI, MN]
Phytophagous		
Edessinae	Edessini	*Ascra bifida* (Say) [NE]
Pentatominae	Aeliini	*Aelia Americana* Dallas [IL, KS, MI, MN, MO, ND, NE, SD]

	Neottiglossa cavifrons Stål [IL, IN, MO]
	Neottiglossa sulcifrons Stål [IA, IL, IN, KS, MI, MN, MO, NE, OH, WI]
	Neottiglossa trilineata (Kirby)[a] [MI, MN, NE]
	Neottiglossa undata (Say) [IA, IL, IN, MI, MN, MO, ND, NE, OH, WI]
Agonoscelidini	*Agonoscelis puberula* Stål [MN, NE]
Cappaeini	*Halyomorpha halys* Stål [IL, MI, MN, MO, NE, OH]
Carpocorini	*Antheminia remota* (Horvath) [ND, NE]
	Coenus delius (Say) [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, WI]
	Coenus inermis Harris & Johnson [MO]
	Cosmopepla intergressa (Uhler) [KS, MO]
	Cosmopepla lintneriana Kirkaldy [IL, IN, KS, MI, MN, MO, ND, NE, OH]
	Cosmopepla uhleri Montandon [NE]
	Euschistus ictericus (Linnaeus) [IA, IL, IN, MI, MN, MO, ND, NE, OH, WI]
	Euschistus latimarginatus Zimmer [KS, MN, ND, NE]
	Euschistus politus (Uhler) [IL, IN, MI, MO, OH]
	Euschistus servus euschistoides (Vollenhoven) [IA, IL, IN, MI, MN, MO, ND, NE, OH]

Euschistus servus servus Say [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH]

Euschistus tristigmus luridus Dallas [IL, IN, MI, MN, MO, ND, NE]

Euschistus tristigmus tristigmus (Say) [IL, IN, KS, MI, MO, NE]

Euschistus variolarius (Palisot) [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH]

Holcostethus abbreviatus Uhler [IA, KS, MN, ND, NE]

Holcostethus fulvipes (Ruckes) [MI, NE]

Holcostethus limbolarius (Stål) [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, WI]

Holcostethus macdonaldi (Rider & Rolston) [IA, IL, MI, MN, ND, NE, SD]

Hymenarcys nervosa (Say)[a] [IA, IL, IN, KS, MI, MO, NE, OH]

Mcphersonarcys aequalis (Say) [IA, IL, IN, KS, MO, MI, NE, OH]

Menecles insertus Stål [IL, IN, KS, MI, MN, MO, ND, NE, OH]

Mormidea lugens (Fabricius) [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI]

Oebalus pugnax (Fabricius) [IA, IL, IN, KS, MI, MN, MO, NE, OH]

Prionosoma podopioides Uhler [IA, IL, KS, MI, MN, MO, NE,]

Proxys punctulatus (Palisot) [IL, IN, MI, MO]

Trichopepla atricornis Stål [IL, IN, KS, MI, MN, ND, OH, WI]

Trichopepla grossa Van Duzee [NE, SD]

Trichopepla semivittata (Say) [IL, IN, KS, MI, MN, MO, NE, OH]

Halyini **	*Brochymena cariosa* Stål [IL, IN, KS, MO, NE, OH, SD]
	Brochymena carolinensis (Westwood) [IN, MO, OH]
	Brochymena punctata punctata [IN, MO]
	Brochymena sulcata Van Duzee [KS, NE]
	Brochymena quadripustulata (Fabricius) [IL, IN, KS, MI, MN, MO, ND, NE, OH]
	Parabrochymena arborea (Say) [IL, IN, KS, MI, MN, MO, ND, NE, OH, SD]
Mecideini	*Mecidea major* Sailer [IL, KS, MN, MO, NE]
	Mecidea minor Ruckes [IA, MN, MO, ND, SD,]
Nezarini	*Chinavia hilaris* (Say) [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI]
	Chinavia pensylvanica (Gmelin) [IA, IL, IN, MI, MN, MO, OH]
	Chlorochroa belfragii (Stål) [IA, IL, MN, ND, NE]
	Chlorochroa faceta (Say) [KS, MO, ND, NE]
	Chlorochroa ligata (Say) [KS, MO, ND, NE, SD]
	Chlorochroa persimilis Horvath [IL, IN, KS, MI, MN, MO, ND, NE, OH]
	Chlorochroa sayi (Stål) [KS, NE]
	Chlorochroa uhleri (Stål) [IN, KS, ND, NE, SD]

Chlorochroa viridicata (Walker) [ND, NE]

Nezara viridula (Linnaeus) [IL, OH]

Pentatomini

Banasa calva (Say) [IL, MI, MN, MO, NE]

Banasa dimidiata (Say) [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, WI]

Banasa euchlora Stål [IA, IL, IN, KS, MO, ND, NE]

Banasa sordida (Uhler) [IL, MI, MN, MO, NE]

Tepa brevis Van Duzee [ND]

Tepa rugulosa (Say) [ND, NE, SD]

Tepa vanduzeei Rider [KS, MO, NE, SD]

Thyanta calceata (Say) [IL, IN, MI, MO, NE]

Thyanta custator accerra (Deay & Gould) [IL, IN, KS, MI, MN, MO, ND, NE, SD]

Thyanta custator custator (Fabricius) [IN, NE, OH]

Thyanta pallidovirens Stål [KS, NE]

Thyanta perditor (Fabricius) [NE]

Piezodorini

Piezodorus guildinii (Westwood) [MO]

Procleticini

Dendrocoris humeralis (Uhler) [IL, IN, KS, MI, MN, MO, NE, OH]

Sciocorini	*Sciocoris microphthalmos* Flor [IA, MI, MN, ND]
Strachiini	*Murgantia histrionica* (Hahn) [IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD]
Podopini	*Amaurochrous brevitylus* Barber & Sailer [IA, IL, KS, MI, MN, MO, ND, NE, WI]
	Amaurochrous cinctipes (Say) [IA, IL, IN, KS, MI, MN, MO, ND, NE]
	Amaurochrous dubius (Palisot) [NE]

* = No generally accepted tribal arrangement.

** = Members of this tribe are both predaceous and phytophagous.

[a] = Location listed as "Dakota" in Froeschner (1988). Assigned to one or both Dakotas only when supplemental information specifies which.

IA (Iowa) - Froeschner (1988)

IL (Illinois) - McPherson (1982)

IN (Indiana) - Blatchley (1926)

KS (Kansas) - Packauskas (2012)

MI (Michigan) - Swanson (2012)

MN (Minnesota) - Koch et al. (2014)

MO (Missouri) - Sites et al. (2012)

ND (North Dakota) - Rider (2012)

NE (Nebraska) - Zimmer (1911, 1912), Wheeler (2015, 2018)

OH (Ohio) - Froeschner (1988), Furth (1974), Welty et al. (2008), Chordas (2015)

SD (South Dakota) – McDonald (1976), Froeschner (1988)

WI (Wisconsin) - Froeschner (1988)

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CHAPTER 3

SPECIES COMPOSITION, ABUNDANCE, AND SEASONAL DYNAMICS OF STINK BUGS (HEMIPTERA: HETEROPTERA: PENTATOMIDAE) IN NEBRASKA CROPPING SYSTEMS

3.1. Abstract

Stink bugs (Hemiptera: Heteroptera: Pentatomidae) have gained considerable attention in Nebraska in the last decade due to increasing densities of native stink bug observed in some locations in Nebraska, and the spread of invasive species in the Midwest. Little is known about stink bug dynamics in Nebraska cropping systems. To address this, we carried out a season-long survey of corn and soybean fields at three locations across eastern Nebraska in 2017, 2018 and 2019 to determine the complex of stink bug species infesting these crops, their relative species composition, seasonal abundance, and to compare current densities to existing recommended thresholds. Crops were sampled weekly by using whole plant examination and sweep net. Altogether, 10 phytophagous species of stink bugs and one predatory species, *Podisus maculiventris* (Say), were collected over the three years of sampling. The most abundant species is the onespotted stink bug, *Euschistus variolarius* Palisot de Beauvois, which made up approximately 83% and 67% of total adult samples collected over three years in corn and soybean, respectively. In soybean, this is followed by the green stink bug, *Chinavia hilaris* (Say) (14.5%) and the redshouldered stink bug, *Thyanta custator acerra* (F.) (12.6%). *Podisus maculiventris*

made up approximately 4.8% of total adults. Overall, pest pressure was higher in soybean than corn. Based on the threshold of five stink bugs per 25 sweeps or 1 stink bug per 0.3 m (1 ft) of row, the combined counts of nymphs and adult stink bug in soybean exceeded this threshold in multiple locations and sampling year. In addition to the species already listed, *Coenus delius* (Say), *Holcostethus limbolarius* (Stål), *Mecidea major* Sailer, and *Murgantia histrionica* (Hahn) were also reported from soybean. Neither of the invasive species, the brown marmorated stink bug, *Halyomorpha halys* (Stål) and the redbanded stink bug, *Piezodorus guildinii* (Westwood) was encountered in crops during this survey This is the first comprehensive survey of stink bug populations in Nebraska crops.

Although the focus of this chapter is corn and soybean, we sampled other crops in eastern and western Nebraska to get a representation of the stink bug fauna likely to be encountered in Nebraska agricultural landscapes, and to understand overall seasonal abundance and voltinism. In total, approximately 3400 adult specimens containing 23 species were recovered. The density of nymphs and adults plotted against sampling dates suggest that stink bugs undergo two generations in Nebraska. This chapter provides information on the species composition, relative abundance, densities, and voltinism of stink bug in Nebraska agroecosystems.

3.2. Introduction

Nebraska is one of the top producers of *Zea mays* L. (corn) and *Glycine max* L. Merrill (soybean) in the United States, with a combined production output of over two billion bushels in 2020 (National Agricultural Statistics Services [NASS] 2021). In the United States, most especially in the southeastern region, phytophagous stink bugs (Hemiptera: Pentatomidae) are major pests of many economically important crops, including corn and soybean (Turnipseed and Kogan 1976, Todd and Herzog 1980, Negron and Riley 1987, Bundy and McPherson 2000, McPherson and McPherson 2000, Panizzi et al. 2000, Temple et al 2013). In the Midwestern and North-Central region, various stink bug species have been reported in field crops. The most encountered species in corn and soybean are *E. variolarius* (Palisot de Beauvois) (onespotted stink bug), *Euschistus servus* (Say) (brown stink bug), *Thyanta custator acerra* McAtee (red-shouldered stink bug), *Chinavia hilaris* (Say) (green stink bug), and *Podisus maculiventris* (spined soldier bug) (Say) (Koch and Pahs 2014, 2015, Koch and Rich 2015, Michel et al. 2015). An increase in the densities of native pentatomid species was observed in Nebraska corn and soybean in the last decade (Wright and Hunt 2008, Hunt et al. 2011, 2014). This observation, coupled with the spread of the invasive species, *Halyomorpha halys* (Stål) (brown marmorated stink bug) and *Piezodorus guildinii* (Westwood) (redbanded stink bug) across the Midwest (Tindall and Fothergill 2011, Tindall et al. 2012, Koch 2014, Michel et al. 2015), has made these pest taxa of particular interest in Nebraska agroecosystems.

Damage caused by stink bugs to corn and soybean has been extensively documented (Turnipseed and Kogan 1976, Todd and Herzog 1980, Panizzi and Slansky 1985, McPherson and McPherson 2000, Panizzi et al. 2000, Bundy and McPherson 2000, Temple et al 2013). Adult and nymphs suck phloem sap from multiple plant parts, including stems, petioles, leaves, flowers, fruits, and seeds. Their feeding activities cause loss of turgor, deformation or abortion of seed and fruiting bodies, delayed plant maturation, dimpling of the fruit's surface, and decay. This leads to yield loss and ultimately, loss of revenue (McPherson et al. 1979, McPherson and McPherson 2000, Musser and Catchot 2008). Economic losses due to stink bug damage and control are valued at millions of dollars every year. For instance, soybean losses due to *Piezodorus guildinii* in Louisiana were ~$28 million (Temple et al. 2013). An annual control cost of $49/ha was reported in Mississippi and Tennessee between 2003 and 2009 (Musser and Catchot 2008, Musser et al. 2009, Musser et al. 2011). Furthermore, yield loss estimates in soybean in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee from 1977 to 1984 ranged from $18-77 million annually per state (McPherson and McPherson 2000). In Georgia alone, depending on year and pest density, loss estimates ranged from $1-23 million for soybean and $2 – 11 million for corn between 1971 and 1998 (McPherson and McPherson 200). Most of these estimates were based on the presence of multiple stink bug species, usually *C. hilaris, N. viridula* and *E. servus* occurring together as a complex.

One of the management approaches to preventing pest populations from reaching levels where they can cause economic losses is the use of action thresholds. Stink bug adults and nymphs both cause injury to plants. Thus, action thresholds for stink bug management are usually determined by the combined number of adults and nymphs of the phytophagous complex per plant or square meter (McPherson and McPherson 2000, Raudenbush et al. 2017, Tilmon 2017). Thresholds vary depending on crop type, end use, region, or species causing the infestation. In the United States, generally recommended thresholds for soybean grown for seed production is five stink bugs per 25 sweeps or one stink bug per 0.3 m (1 ft) of row and 10 stink bugs per 25 sweeps or three stink bugs per 0.3 m (1 ft) of row for soybean grown for grain (Kogan 1976, Michel et al. 2013). The general threshold for stink bug in Louisiana soybean is nine stink bugs per 25 sweeps (Temple et al. 2013a). Whereas the threshold for the invasive stink bug *P. guildinii* in the same region is six stink bugs per 25 sweeps or 0.6 stink bugs per 0.3 m (1 ft) due to the ability of this species to cause more damage to soybean than other stink bug species (Baur and Baldwin 2006). In corn, thresholds vary with the developmental stage of the plant. For plants 0.6 m and below, treatment is recommended when 10% or more of plants have stink bugs. During ear development and the start of pollen shed, the threshold is one stink bug per four plants or 25% of plants and one stink bug per two plants or 50% of plants from pollen shed to early dough stage (Hunt et al. 2011, 2014). An assessment of *Euschistus servus* feeding injury on corn estimated an economic injury level (EIL) of seven stink bugs per 100 plants or 7% in seedling corn and 12 stink bugs per 100 plants or 12% from VT through pollination (Bryant et al. 2020). This signifies an economic threshold that is lower than those previously proposed.

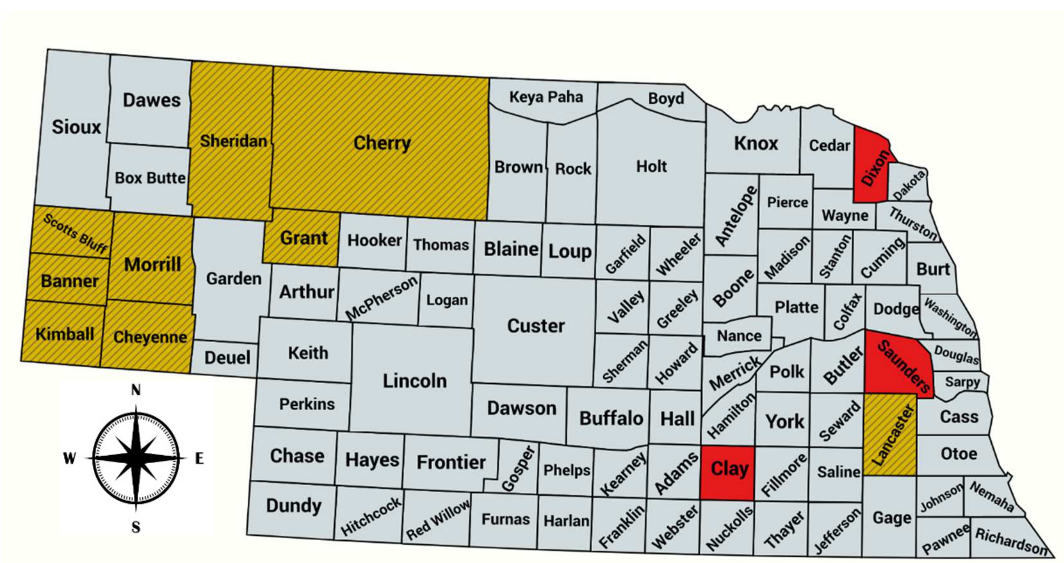
In Nebraska, extensive research has been carried out on various aspects of the biology and management of major pests of corn and soybean such as corn rootworm *Diabrotica* spp. Chevrolat (Pruess et al. 1968, 1974, Darnell et al. 2000, Meinke et al. 1989, Urias-Lopez et al. 2000, Wright et al. 2000), western bean cutworm *Striacosta albicosta* (Smith) (Appel et al. 1993, Paula-Moreas et al. 2011, Hanson et al. 2015, Montezano et al. 2017), soybean aphid *Aphis glycines* Matsumura (Ragsdale et al. 2007, Brosius et al. 2007, 2010, Tiroesele et al. 2012, Marchi-Werle et al. 2017, Baldin et al. 2018), and bean leaf beetle *Cerotoma trifurcata* (Forster) (Hunt et al. 1994, 1995, Tiroesele et al. 2014, Tietjen et al. 2017). In comparison, previous studies on stink bug specific to Nebraska are very limited, and mostly taxonomic in nature (Zimmer 1912, Wheeler 2015, 2018). Crop-related studies were a preliminary survey in corn and soybean fields where the increased densities of native stink bug species were initially observed in Nebraska (Hunt et al. 2011, Hunt et al. 2014), and sampling plans for estimating stink bug densities in the north central region which includes Nebraska (Pezzini et al. 2019, Aita et al. 2021). The paucity of information on the stink bug ecology and management in Nebraska agroecosystems suggest that stink bugs are historically not pests of concern in agricultural production until recently. This season-long survey of corn and soybean fields document the pentatomid fauna associated with these crops, as well as their seasonal and population dynamics in Nebraska. This information is important for developing management strategies and serve as baseline for monitoring future shifts in population parameters.

3.3. Materials and Methods

Field locations

Studies specific to corn and soybean were conducted at three experiment stations maintained by the University of Nebraska-Lincoln (Fig. 3.1); Haskell Agricultural Laboratory (HAL) in Concord, Dixon County, Eastern Nebraska Research and Extension Center (ENREC) near Ithaca, Saunders County and South-Central Agricultural Laboratory (SCAL) near Clay Center, Clay County. At each location, two corn and two soybean fields were selected and sampled in summer of 2017, 2018 and 2019. A total of 18 fields were sampled per crop. Field size ranged from 2.6 to 36 ha (Mean ± SEM: 13.5 ± 1.7 ha). Fields were chosen without prior knowledge of agronomic practices, plant quality, or pest pressure. In addition to corn and soybean, stink bug samples were collected from wheat, alfalfa, conservation buffers, as well as grasses and shrubs at nine other locations (Fig. 3.1).

Figure 3.1. Locations where stink bug samples were collected. Red represents research fields where diversity and abundance in soybean and corn fields were carried out all season-long from 2017 to 2019; HAL (Haskell Ag. Lab, Dixon Co.), ENREC (Eastern Nebraska Research and Extension Center, Saunders Co.) and SCAL (South Central Ag. Lab, Clay Co.). Yellow indicates other locations where stink bug samples were collected.



Data collection

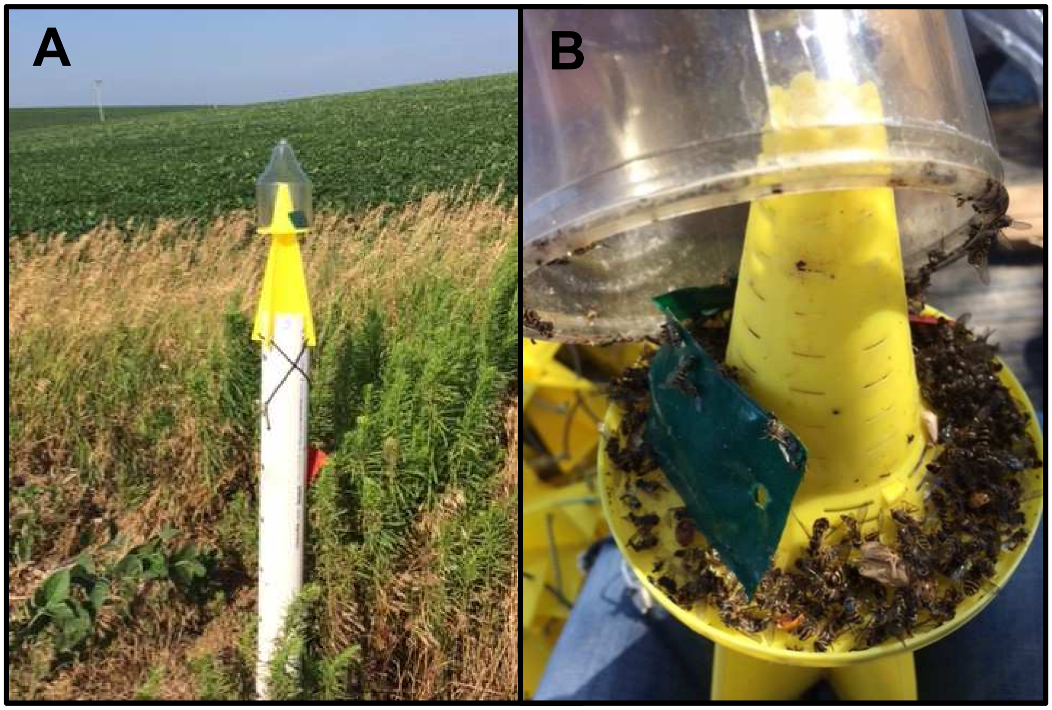
Stink bug adults and nymphs were collected form corn and soybean at approximately weekly intervals in summer from June through September. Three sampling methods, sweeps, transects (visual count), and pheromone-baited pyramid traps were used. Sweeps and transects were modified from Suh et al. (2013), Venugopal et al. (2014) and Koch and Pahs (2015), while pyramid trap dimension and deployment was modified from Leskey and Hogmire (2005), Hogmire and Leskey (2006) and Leskey et al. (2015). Sweep nets and transects were used for sample collection in all three years except for 2017 when pheromone-baited pyramid traps were deployed in addition to sweeps and transects. For each sample unit, content from either the sweep net, visual count or pheromone-baited trap were emptied into resealable plastic bags which were transported to the laboratory and stored in a refrigerator until processing.

Transects. In each field, the sampling layout consist of two transects spaced 100m apart and about 100m away from field borders on either side. Along each transect, six sets of six consecutive plants were sampled at 0, 2, 10, 30, 50 and 100m from edge to interior of field. Whole plants were visually examined for the presence of nymphs and adults. Twenty four sampling units (144 plants) were assessed per crop per location on each sampling date. The sampling unit of six consecutive plants is equivalent to approximately 0.3 m or one ft of row. This method was used in both corn and soybean.

Sweeps. Sweep samples were collected by sweeping two adjacent rows at 180^{o} movement using a 38 cm wide sweep net. Each field was sampled by taking 10 sets of sweeps (one set of sweep equals 25 random sweeps). A total of 20 sets of sweeps (500 sweeps) were taken at each location on each sampling date. This method was used not used in corn.

Pheromone-baited pyramid trap. Pyramid height from base to cone is 1.5m. Base is made of 13cm diameter white PVC pipe. A yellow cross vein cone is mounted on each base and the top of each cone is covered with a transparent jar (Figure 3.2a). MDT Lures (Ag-Bio Development Inc, Westminster, CO) containing aggregation pheromone of *Plautia stali*, Brown□winged green stink bug (methyl (E, E, Z) □246 □ decatrienoate), was placed in the transparent jar atop each trap. This was replaced every four weeks for effectiveness. Insecticidal strip containing 10% 2,2-dichlorovinyl dimethyl phosphate (Vaportape II, Hercon Environmental, Emigsville, PA) was placed inside each trap along with the pheromone lure to prevent the escape of stinkbugs. This has been shown to increase trap efficiency by approximately 250% (Leskey et al. 2012). Kill strips (5 cm long × 2.5 cm wide) were also replaced monthly. Four traps were placed per field, one on each border, approximately 1m away from crop. A total of 16 traps were deployed in both corn and soybean at each location. Traps were checked weekly, and the content sorted out for the presence of stink bugs (Figure 3.2b). Specimens collected from this method were excluded from the yearly data to allow for accurate comparison of diversity and abundance between years, however, the species collected from this method only are indicated in Table 3.1. In addition to the methods already listed, blacklight traps were also used for collection as indicated in Table 3.1.

Figure 3.2. Pheromone-baited pyramid trap mounted in the field (A), transparent jar opened to access content (B). Photograph by Blessing Ademokoya.



Identification and Species Composition

Adults were identified to species based on morphological features using taxonomic keys (e.g., McPherson 1982, Larievere 1988, Packauskas 2012, Thomas 2012, Rider 1986, 2012, Paiero et al. 2013). Relative abundance was calculated as a percentage of the number of adult individuals of a given species relative to the total number of adults of all species combined.

Data Analysis

All data irrespective of sampling method were pooled across locations and years to determine the overall diversity of stink bug in Nebraska agroecosystems. Also, the same method was used to compare the abundance of nymphs to adults at different sampling dates during the season to determine voltinism. However, due to disproportionate nymph representation, samples from black light and pheromone-baited traps were excluded from the voltinism data. For the crops of interest (corn and soybean), data from fields of the same crop in the same location were pooled for each sampling year. Overall complex of stink bug species in each crop was determined based on the pooled data from all locations. Descriptive characteristics of data such as ratios, averages, percentages, and sums were calculated. Averages of sweeps and transects in corn and soybean were compared with action threshold recommendations for neighboring states to determine the severity of stink bug infestation in Nebraska.

3.4. Results and Discussion

A combined count of 899 adult stink bugs (823 for soybean and 76 for corn) were collected from ENREC, HAL and SCAL during the three sampling years using sweep and transect method. Ten phytophagous stink bugs and one predatory species were recovered from both crops (Table 3.2). The diversity of stink bug in soybean was higher than corn in each year of sampling and at all locations (Figures 3.3a, b, 3.4a, b). Overall, 11 species were collected in soybean while five species were collected in corn. Four phytophagous species *E variolarius*, *E. tristigmus tristigmus*, *E. tristigmus luridus*, *T. custator acerra* and the predatory stink bug *Podisus maculiventris* were commonly collected from both corn and soybean. The most abundant species was *E variolarius* with an overall value of 67.9% of total adults (82.9% and 66.5% in soybean and corn respectively). This was followed by *C. hilaris* at 13.2% (14.5% in soybean) and *T. custator accerra* at 11. 9% (12.6% and ~4% in soybean and corn, respectively). The spined soldier bug, *P. maculiventris* made up approximately 4.8% of total. No predatory species was recovered from corn in 2017. In a similar survey carried out in Minnesota corn and soybean, four herbivorous adult species and one predatory were collected in corn (Koch and Pahs 2015), while twelve herbivorous adult species and two predatory were collected in soybean (Koch and Pahs 2014). The phytophagous stink bug complex in corn consisted of *E. variolarius, E. ictericus*, *E. tristigmus luridus,* and *E. servus euschistoides* with *E. variolarius* being the most predominant species and accounting for approximately 82% of samples collected in corn in one of the sampling years (Koch and Pahs 2015). In soybean, the most abundant phytophagous species were *E. variolarius* (60.5%), *E. servus euschistoides* (19.0%), *C. hilaris* (5.5%), and *E. tristigmus luridus* (3.2%) (Koch and Pahs 2014). A similar trend was observed in Minnesota wheat (Koch et al. 2015). This suggests that *E. variolarius* is the species with the most potential to build up to pest densities in field crops in the Midwest. The species composition in corn and soybean in the southeastern part of the United States is slightly different. Suh et al. (2013) reported *Euschistus servus* as the most abundant species in Texas corn and soybean accounting for up to 83% and 67% respectively. Whereas the stink bug complex reported in Arkansas soybean is made up of *N. viridula* (59%), *Euschistus servus* (20%), *Acrosternum hilare* (syn = *C. hilare*) (16%), and *Thyanta* spp. and *P. guildinii* combined made up 5% of total stink bugs. (Smith et al. 2009). In

Georgia, *N. viridula, Acrosternum hilare* and *Euschistus servus* were also the most predominant species in corn and soybean (Bundy and McPherson 2000)

Aside the diversity being higher in soybean, it is also the crop with the most pest pressure as shown in the combined counts of nymphs and adults (Figures 3.3a, b). For accurate comparison, data from transects alone were compared for both crops (Figure 3.3a). In all three years, the total number of stink bugs adult and nymphs was 176 in corn and 379 in soybean for the same number of sampling units. This is not surprising as stink bugs are known to prefer soybean over corn (Panizzi and Slansky 1985, Todd 1989, Bundy and McPherson 2000). There is no economic threshold hold specific to Nebraska, however, based on the threshold of five stink bugs per 25 sweeps or one stink bug per 0.3 m (1 ft) of row, the combined counts of nymphs and adult stink bug in soybean using the visual count method exceeded this threshold in ENREC 2017 (1.2 stink bug/0.3 m), ENREC 2018 (2 stink bug/ 0.3 m), ENREC 2019 (1.6 stink bug/ 0.3 m) and SCAL 2018 (5.2 stink bug/ 0.3 m) (Figure 3.7b). For sweep samples, the average value of stink bug/25 sweeps was 18 for SCAL in 2018 and seven for ENREC in 2019 (Figure 3.7c). Averages of transect samples in corn did not reach the action threshold (Figure 3.7a) and pest pressure was generally low at HAL. The overall population of stink bug peaked in August (Figure 3.4A). This period coincides with the reproductive stage of corn and soybean when stink bugs move into cultivated plants to feed on developing pods and fruits. A higher abundance was observed in 2018 compared to 2017 with SCAL being the location with the most abundance. A similar trend was expected for 2019, however, stink bug densities reduced especially in SCAL where a hailstorm decimated the crops in August just about when population usually peaks. The relative abundance in each crop showed that *E. variolarius* is the most abundant, irrespective of sampling year or location (Figure 3.4a, b). Despite being the second most abundant in soybean, *C. hilaris* was not encountered in corn at any of the locations throughout the three years of sampling. Similarly, in a survey carried out in Georgia, *C. hilaris* was not collected in corn (Herbert and Toews 2011, 2012). Also, this species was not recovered at all in HAL, Dixon County in any of the three years (Figure 3.4a, b). In addition to the species already mentioned, *E. servus servus*, *Coenus delius*, *Holcostethus limbolarius*, *Mecidea major,* and *Murgantia histrionica* were also recorded from soybean with a <2% combined count. The last four species are seldomly found in corn and soybean and they are usually not pests of concern when present (Suh et al. 2013).

When temperature rises in spring, adult stink bugs emerge from overwintering sites and move to nearby plants. This could be early planted crops such as wheat, or wild hosts such as shrubs, trees, and grasses where they feed, mate, and lay eggs (McPherson 1982, Panizzi 1997). Populations build up on these initial host plants, and they often move into cultivated crops later in the season. As the season progresses, they move from senescing crops to preferably, other crops in reproductive growth stages (Panizzi 1997, Pilkay et al. 2015). In Nebraska, planting of corn and soybean typically starts in late April to early May. Stink bugs are important early-season pest of field crops in the southern United States (Townsend and Selacek 1986, Annan and Bergman 1988, Bryant et al. 2020). Damage to seedling corn can cause stunted growth, leaf injury, tillering and even plant death. This injury has the potential to lead to eventual yield loss even when the plant survives (Bryant et al. 2020). Corn seedlings were in the V2 growth stage were checked for stink bug feeding damage in May of 2017 at ENREC. Although the survey yielded no stink bug samples, lots of seedlings showed signs of stink bug feeding damage (Figure 3.6). Both overwintering adults and nymphs of *Euschistus* spp. were collected from Nebraska fields as early as May. This suggests that overwintering adults lay eggs in wild hosts or early planted crops as soon as they move out of their shelter in early April. These eggs hatch into nymphs which undergo five instars to become the 1st generation adults. A surge in population and a second wave of nymphs were observed starting from late July through August (Figure 3.5a, b). This implies that the 1st generation adults reproduced to give rise to these 2nd generation. As temperatures start to drop towards the end of the season, the second generation looks for overwintering sites and the cycle is repeated. Stink bugs undergo many generations per year depending on photoperiod (Wilde 1969). In North America, the number of generations per year range from one (univoltine) in the north to five (multivoltine) in the extreme south (Javahery 1990, Kamminga et al. 2009, McPherson and McPherson 2000). In the Midwest, the number of generations per year is usually one or two (McPherson 1982). Based on the population of nymphs and adult collected over this three years period, we can conclude that the stink bug population in Nebraska undergoes two generations (Figure 3.5B).

All the samples collected from wheat, alfalfa, conservation buffers, grasses, and shrubs as well as those collected from blacklight trap added up to approximately 3400 adult specimens and 24 species (Table 2). The most abundant species is *E. variolarius* (65.9%), which also happened to be the most abundant in corn and soybean. *Cosmopepla Lintneriana* and *Thyanta pallidovirens* were collected from pheromone-baited trap only while *Tepa rugulosa*, *Banasa dimidiata* and *B. sordida* were collected from black light trap only. The relative abundance of species collected from the blacklight trap differ from the samples collected through other methods. Of the 6 species, *C. hilaris* was the most abundant at 65.2%, followed by *E. variolarius* at 25.7%. Species like *Brochymena quadripustulata, Chlorochroa ligata* and *C. sayi* were collected only from western Nebraska (Figure 3.8). The invasive species, *H. halys* and *P. guildinii* were not recovered from crops during this survey. However, a single specimen of *H. halys* was collected from a residential area in 2019 in Lancaster County. *Halyomorpha halys* has been reported in soybean in nearby Missouri (Bailey 2009) and Ohio (Michel et al. 2013) while *P. guildinii* is an established pest of soybean in the southern United States (Smith et al. 2009, Tindall and Fothergill 2011, Temple et al. 2013).

Reports of increasing populations of native stink bug species in Nebraska as well as damage to seedling corn was noticed and reported by crop consultants in 2008 (Wright and Hunt 2008). Since then, the populations of stink bug in Nebraska fields have increased up to noticeable levels. A preliminary survey conducted in corn and soybean fields between 2009 and 2011 yielded four species of stink bugs, *C. hilaris, E. servus, E. variolarius*, and *T. custator acerra* (Hunt et al. 2011). This recent survey yielded 11 species in corn and soybean, and 23 species in all the crops that were sampled. This increase in diversity and density, in addition to the spread of exotic species through the Midwest, necessitated the need for this current study. Data from this study confirms that Pentatomids, most importantly *E. variolarius* and *C. hilaris,* are emerging pests of field crops, especially soybean in Nebraska.

Table 3.1. Species composition of stink bug adults collected across all agricultural landscapes in Nebraska in 2017 (n=416), 2018 (n=1723) and 2019 (n = 1208); n = total number of adult stink bugs collected. (a) indicate specimens that were collected only from

western Nebraska, (b) indicates specimens collected only from pheromone-baited trap and (c) indicates specimens collected only from black light trap.

Stink bug species	Relative Abundance (%)		
	2017	2018	2019
Phytophagous			
Banasa dimidiata	_	0.12[c]	_
Banasa sordida	_	_	0.08 [c]
Brochymena quadripustulata	_	_	0.08[a]
Chinavia hilaris	_	25.5	13.5
Chlorochroa ligata	_	_	1.08[a]
Chlor ochroa persimilis	_	0.12	_
Chlorochroa sayi	_	_	0.17[a]
Coenus delius	0.24	0.06	0.4
Cosmopepla lintneriana	0.96[b]	0	0
Euschistus servus euschistoides	_	0.06	0
Euschistus servus servus	0.24[b]	0.06	0.08
Euschistus tristigmus luridus	0.96	0.12	0.33
Euschistus tristigmus tristigmus	1.68	0.12	0.33
Euschistus variolarius	73.3	65.6	66.4
Holcostethus limbolarius	0.48	0.06	0.5
Holcostethus fulvipes	_	_	0.08
Mecidea major	0.48	0.06	_
Murgantia histrionica	2.40[b]	0.06	_
Tepa rugulosa	_	0.17[b]	_
Thyanta calceata	_	0.12	_

Thyanta custator acerra	16.8	5.46	3.23
Thyanta pallidovirens	0.24[b]	_	_
Predatory			
Podisus maculiventris	2.16	2.49	13.5

Table 3.2. Stink bug species encountered in soybean and corn in Nebraska. (+) indicates presence, (-) indicates absence, and (+*) indicates single specimen collected from crop during a particular year crop.

Stink bug species	Corn			Soybean		
	2017	2018	2019	2017	2018	2019
Phytophagous						
Coenus delius	_	_	_	_	+*	+*
Chinavia hilaris	_	_	_	_	+	+
Euschistus servus servus	_	_	_	_	_	+*
Euschistus tristigmus luridus	_	+	_	_	+	+
Euschistus tristigmus tristigmus	+*	+*	+*	+*	_	+
Euschistus variolarius	+	+	+	+	+	+
Holcostethus limbolarius	_	_	_	_	_	+*
Mecidea major	_	_	_	_	+*	_
Murgantia histrionica	_	_	_	_	+*	_
Thyanta custator acerra	_	+	_	+	+	+
Predatory						
Podisus maculiventris	_	+*	+	+	+	+

Figure 3.3. Abundance of stink bug (adult + nymphs) collected in soybean and corn from transects only (A), sweep net + transect (B), in 2017, 2018 and 2019.

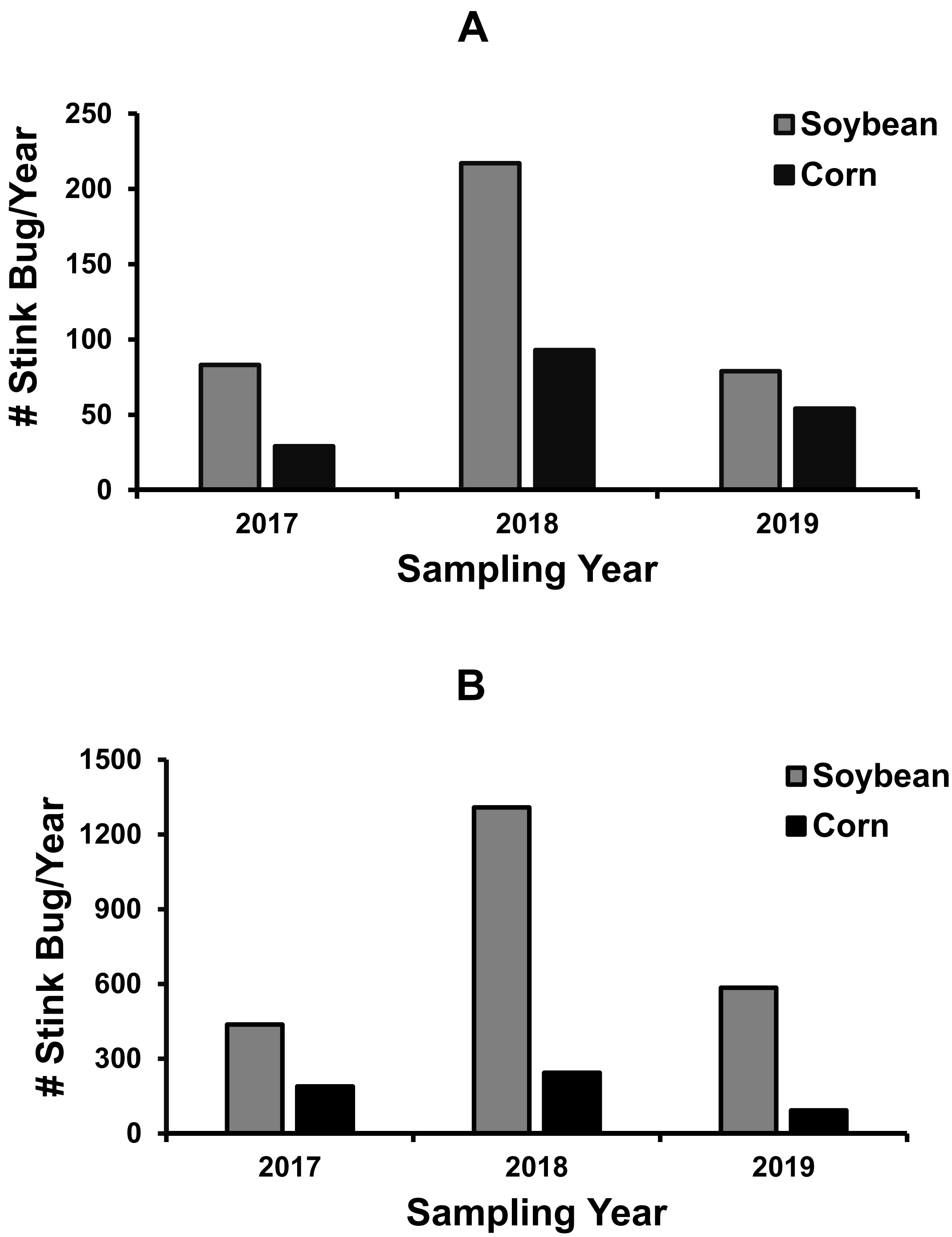
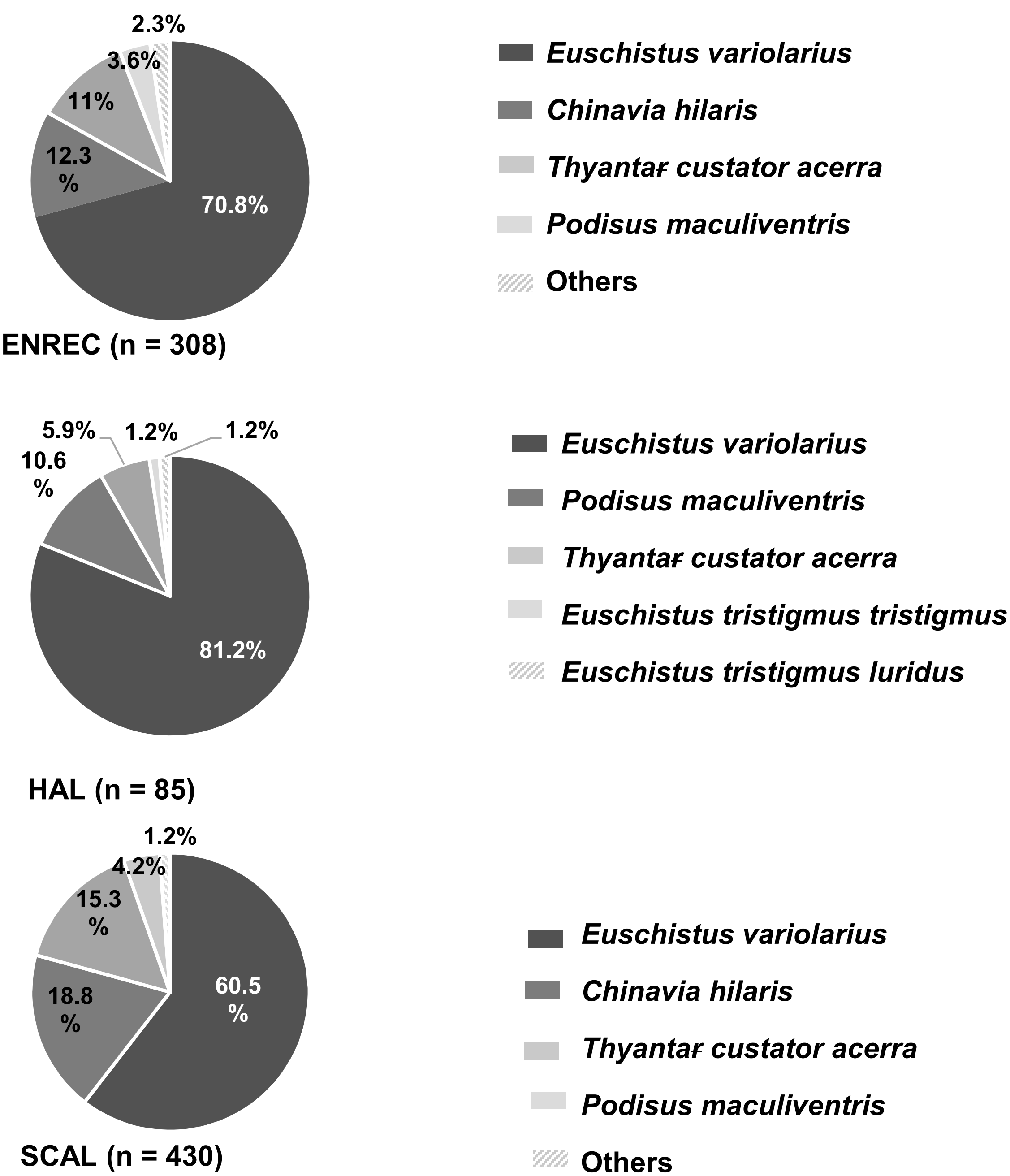


Figure 3.4. Relative abundance of stink bug species by field location, based on three years (2017, 2018 and 2019) count of adults collected from sweep and transect, soybean (A) and corn (B).

(A)



(B)

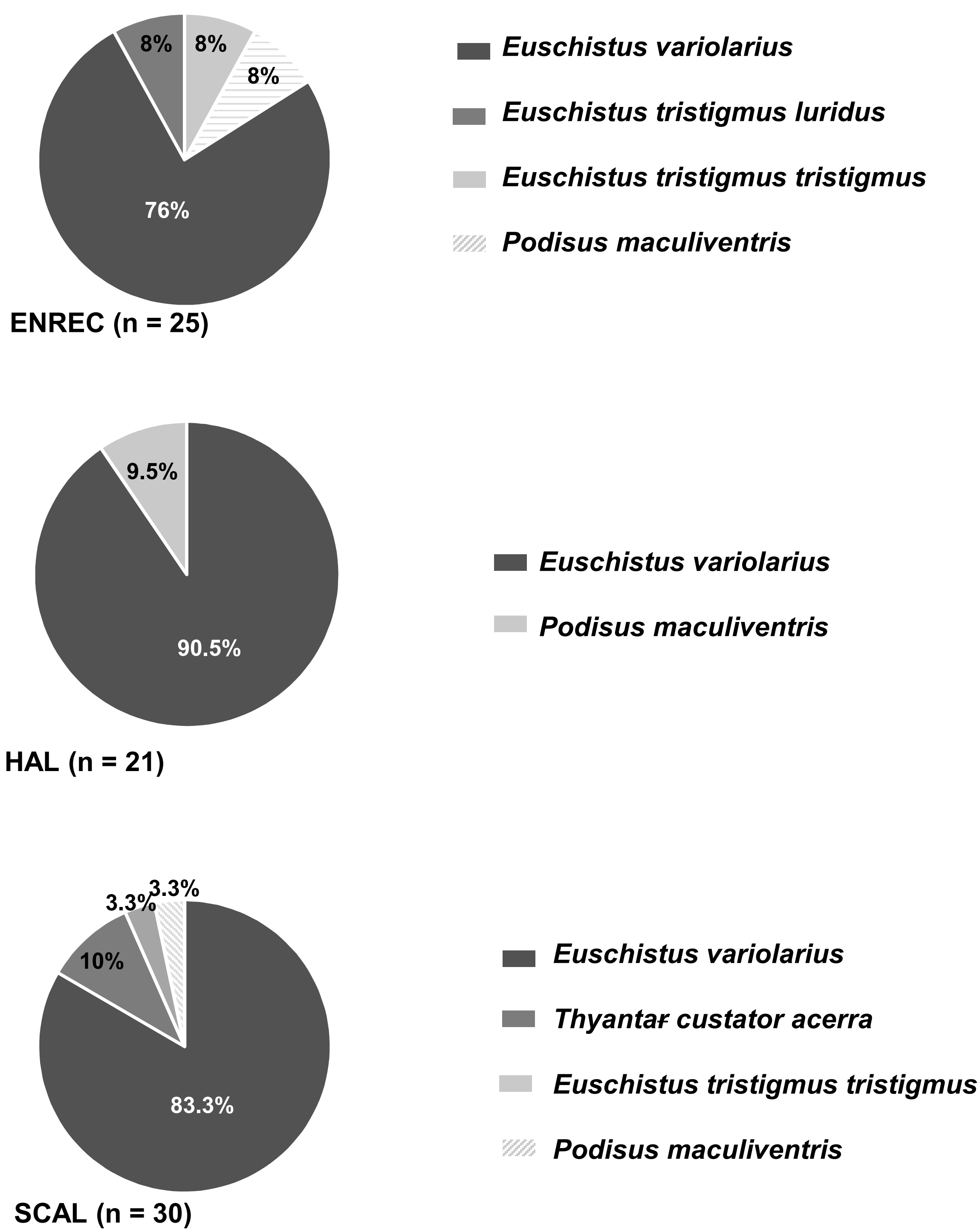
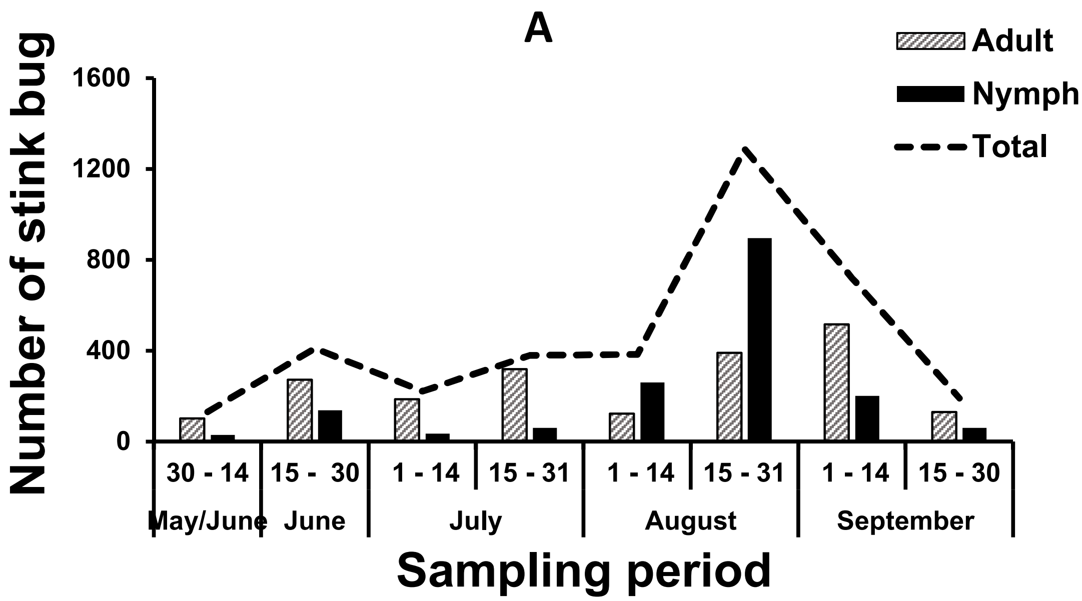

8%
8%
8%
76%
Euschistus variolarius
Euschistus tristigmus luridus
Euschistus tristigmus tristigmus
Podisus maculiventris
ENREC (n = 25)
9.5%
90.5%
Euschistus variolarius
Podisus maculiventris
HAL (n = 21)
3.3%
3.3%
10%
83.3%
Euschistus variolarius
Thyantar custator acerra
Euschistus tristigmus tristigmus
Podisus maculiventris
SCAL (n = 30)

Figure 3.5. Season-long abundance of stink bugs in Nebraska agricultural landscapes (2017-2019). Abundance of nymphs and adults by month (A), nymphs vs. adults showing the likely number of stink bug generations in Nebraska (B).



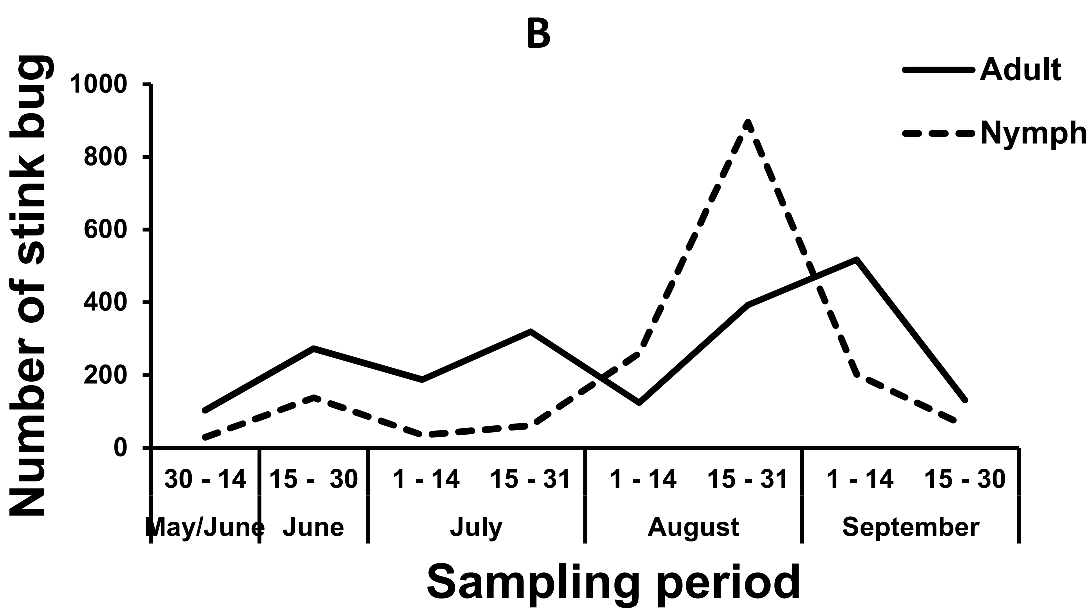
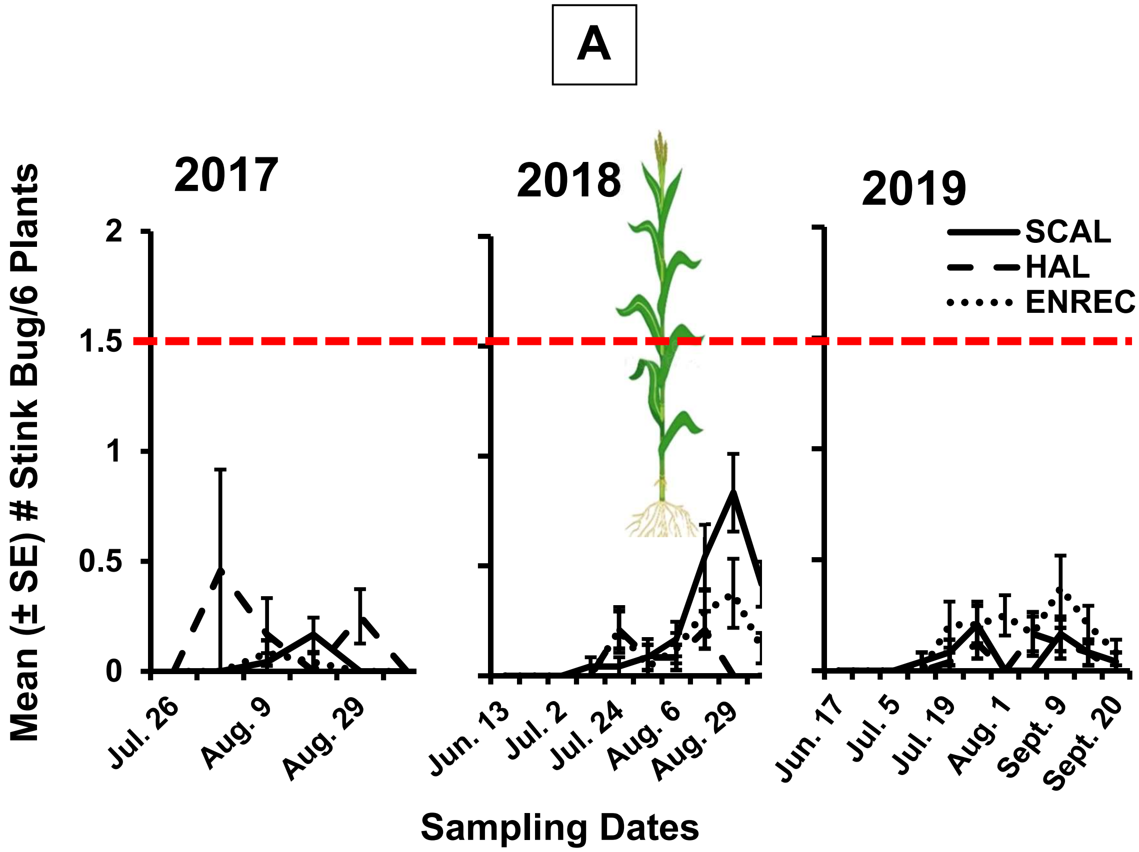
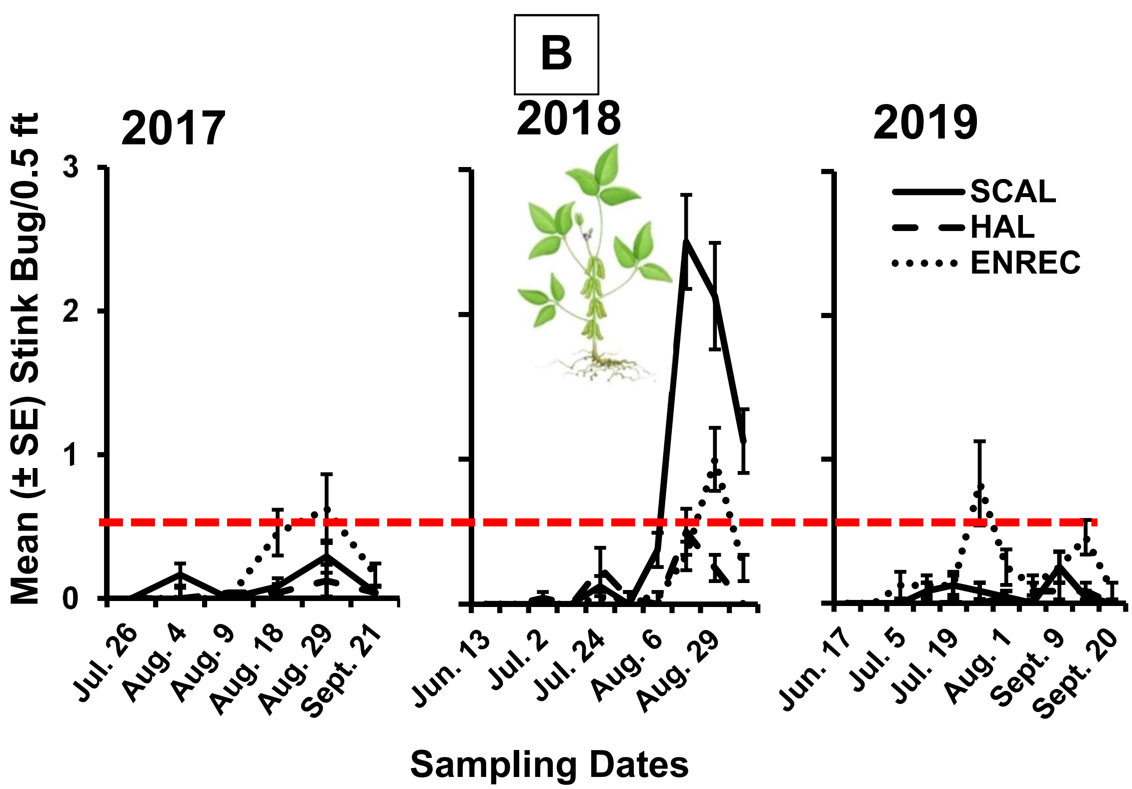


Figure 3.6. Seedling corn at ENREC showing signs of stink bug damage. Photograph by Blessing Ademokoya.

Figure 3.7. Mean values of stink bug (Adult + Nymph) collected in corn using transect method (A), soybean using transect method (B) and soybean using sweep net (C). This shows the stink bug densities in Nebraska relative to recommended action thresholds (red broken lines).


A
2017
2018
2019
SCAL
HAL
ENREC
Mean (± SE) # Stink Bug/6 Plants
2
1.5
1
0.5
0
Jul. 26
Aug. 9
Aug. 29
Jun. 13
Jul. 2
Jul. 24
Aug. 6
Aug. 29
Jun. 17
Jul. 5
Jul. 19
Aug. 1
Sept. 9
Sept. 20
Sampling Dates


B
2017
2018
2019
SCAL
HAL
ENREC
Mean (± SE) Stink Bug/0.5 ft
3
2
1
0
Jul. 26
Aug. 4
Aug. 9
Aug. 18
Aug. 29
Sept. 21
Jun. 13
Jul. 2
Jul. 24
Aug. 6
Aug. 29
Jun. 17
Jul. 5
Jul. 19
Aug. 1
Sept. 9
Sept. 20
Sampling Dates

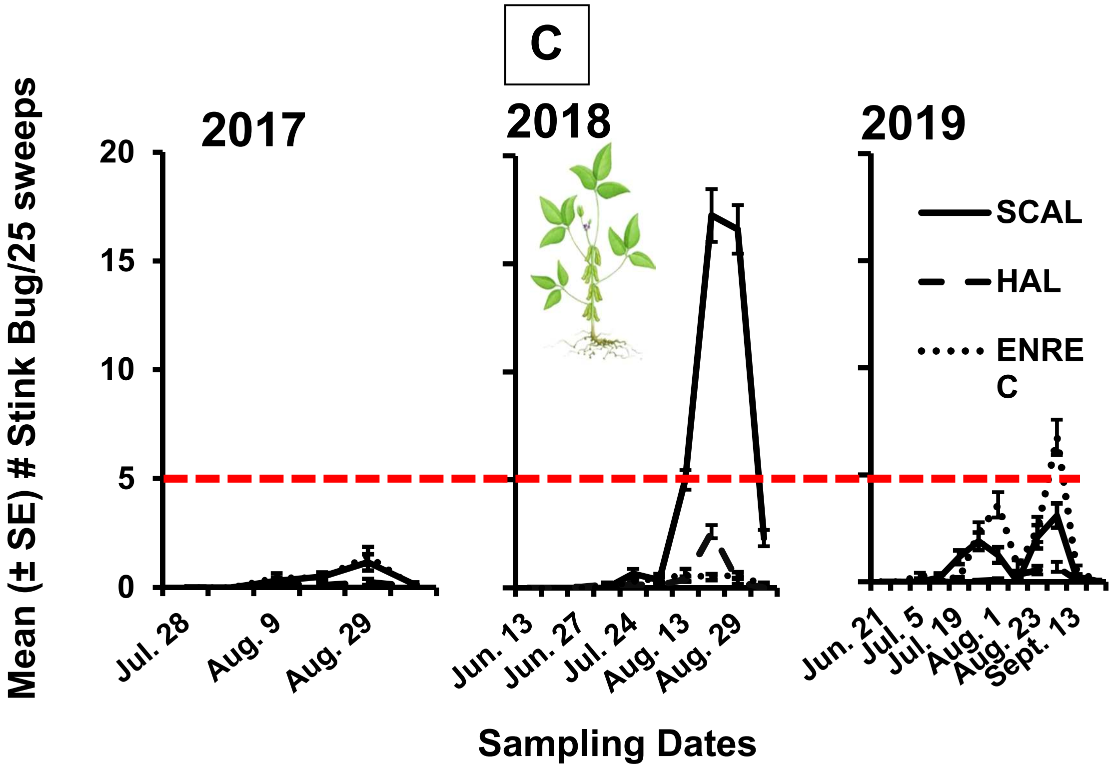
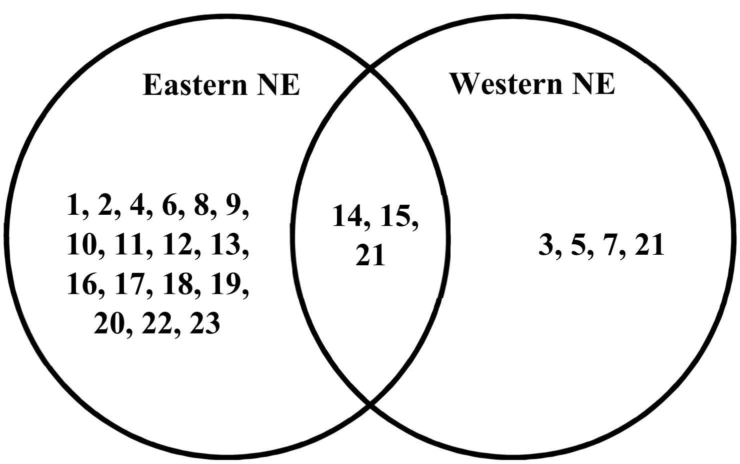


Figure 3.8. Comparison of diversity between eastern NE (Dixon Co., Clay Co., Saunders Co., Lancaster Co.) and western NE (Cheyenne Co., Banner Co., Grant Co., Cherry Co., Morrill Co., Sheridan Co., Kimball Co.) based on combined data from all sampling methods, crops, and years.



1. *Banasa dimidiata* **2.** *Banasa sordida* **3.** *Brochymena quadripustulata* **4.** *Chinavia hilaris* **5.** *Chlorochroa ligata* **6.** *Chlorochroa persimilis* **7.** *Chlorochroa sayi* **8.** *Coenius delius* **9.** *Cosmopepla lintneriana* **10.** *Euschistus servus euschistoides* **11.** *Euschistus servus servus* **12.** *Euschistus tristigmus luridus* **13.** *Euschistus tristigmus tristigmus* **14.** *Euschistus variolarius* **15.** *Holcostethus limbolarius* **16.** *Holcostethus fulvipes* **17.** *Mecidea major* **18.** *Murgantia histrionica* **19.** *Tepa rugulosa* **20.** *Thyanta calceata* **21.** *Thyanta custator acerra* **22.** *Thyanta pallidovirens* **23.** *Podisus maculiventris*

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CHAPTER 4

SPATIAL DISTRIBUTION OF STINK BUGS (HEMIPTERA: HETEROPTERA: PENTATOMIDAE) IN NEBRASKA CORN AND SOYBEAN

4.1 Abstract

Stink bug (Hemiptera: Heteroptera: Pentatomidae) has gained considerable attention in Nebraska in the last decade. Knowledge of dispersal behavior and within-field distribution pattern of phytophagous pests is important in making management decisions. Thus, this study was conducted to understand the spatial distribution of stink bugs in Nebraska corn, *Zea mays* L. and soybean, *Glycine max* L. For both crops, weekly sampling was carried out at three locations in eastern Nebraska over a three-year period. Average counts of stink bug adults and nymphs taken over the season at designated points between field edge and field interior showed no significant effect of distance except for a single location in 2017. Stink bug densities when averaged over the season is below the recommended threshold for the Midwest. However, samples taken at ENREC and SCAL during peak period (July – August) exceeded this threshold. At the time of this study, field scale distribution of stink bug in Nebraska agroecosystem is random, and densities are not economically significant.

4.2 Introduction

Stink bugs (Hemiptera: Heteroptera: Pentatomidae), like other mobile phytophagous pests move between cultivated and non-cultivated habitats. The resultant distribution pattern is influenced by factors such as crop phenology, surrounding vegetations and stink bug oviposition behavior (McPherson 1982, (Panizzi 1997, Pilkay et al. 2015). For instance, stink bugs lay eggs in clusters and first instar nymphs are gregarious in nature (Kiritani et al. 1965, McPherson 1982, Todd 1989), this tends to generate a clumped distribution pattern at this stage (Todd 1989). Also, stink bug populations usually build up on initial host plants, usually wild hosts, or early planted crops, from where they colonize adjacent fields (Panizzi 1997, Tillman et al. 2013, Pilkay et al. 2015). This could generate edge effect. Furthermore, adult stink bugs are very active, and as the season progresses, they move from crop to crop, usually from senescing crops to preferably, other crops in reproductive growth stages (Panizzi 1997, Pilkay et al. 2015). Other factors that can influence stink bug dispersal include, proximity, host suitability and preference (Jones and Sillivan 1982, Velasco and Walter 1992, Panizzi 1997, McPherson and McPherson 2000, Siebert et al. 2005).

There are variations in the distribution pattern of stink bug in studies addressing spatio-temporal occurrences. Some studies have demonstrated that stink bug species show edge effect, that is, they are likely to be more concentrated along field borders compared to field interior (Tillman et al. 2009, Reay-Jones et al. 2010, Reeves et al. 2010, Venugopal et al. 2014). However, there are other studies that show that stink bugs aggregate at the border as well as field interior at different levels depending on the species, developmental stage, and field location (Pezzini et al. 2019). Aside first instar nymphs, adult *N. viridula* have a clumped distribution pattern in soybean fields in the United States (Todd and Herzog 1980). Within field aggregation may be influenced by pheromones or vibrational signals (Harris and Todd 1980, Tillman et al. 2010, Lampson et al. 2010, Lampson et al. 2013). Another distribution patter is within-plant distribution in which the sampling scale is reduced to individual plants. Here, stink bug density shows non-random vertical distribution and it's directly proportional to the developmental stage of the plant (Russin et al. 1987, Blinka 2008, Owens et al. 2013, Babu and Reisig 2018).

Phytophagous stink bugs are important pests of many economic crops in the southeastern United States (Turnipseed and Kogan 1976, Todd and Herzog 1980, Panizzi and Slansky 1985, McPherson and McPherson 2000). However, they are not a threat to agricultural production in the Midwest until recently (Koch and Pahs 2014, 2015, Koch and Rich 2015). This recent development has been attributed to the detection of invasive species like *Halyomorpha halys* and *Piezodorous guildinii* in the Midwest (Tindall and Fothergill 2011, Tindall et al 2012, Koch 2014), as well as noticeable increase in the density of native species (Michel et al. 2013). Understanding the spatial distribution of stink bugs in Nebraska agroecosystem is important for making management decisions such as selective pesticide application, trap cropping and the deployment of biological control agents.

4.3 Materials and Method

Data collection

Stinkbugs were collected each week during the 2017, 2018, and 2019 growing season at three locations (ENREC, HAL, and SCAL). Stink bugs were collected from corn and soybean using two sampling methods, sweeps, and transects (visual count). Collection methods were modified after Suh et al. (2013), Venugopal et al. (2014) and Koch and Pahs (2015). Transect layouts consist of two transects spaced 100 m apart and about 100m away from field borders on either side. Along each transect, six sets of six consecutive plants were sampled at 0, 2, 10, 20, 50 and 100m from edge to interior of field. Whole plants were visually examined for the presence of nymphs and adults. 24 sampling units (144 plants) were assessed per crop per location on each sampling date. This method was used in both corn and soybean. Sweep samples were collected by sweeping two adjacent rows at 180^o movement using a 38 cm wide sweep net. 10 sets of sweeps (one set of sweep equals 25 random sweeps) were taken at 0, 2, 10, 20, 50 and 100m. A total of 20 sets of sweeps (500 sweeps) were taken at each location on each sampling date. This method was used in soybean only. See chapter 3 for more field details.

Data Analysis

Exploratory data analysis, that is, analyzing the total number of adults and nymphs averaged across each sampling date was not feasible due to weekly low counts. To test for differences in abundance between samples collected from field edge (0m - 20m) and field interior (50m - 100m), the difference in the average counts for distances designated as either edge or interior for each sampling method, location, crop, and year, were compared to zero. Results for this were mostly insignificant. We therefore approached this analysis by summing up the number of stinkbugs collected the entire season at each sampling point, that is, 0, 2, 10…100m and comparing abundance among the sampling points for each year and sampling method. Data was analyzed using a generalized linear mixed model (GLMM) following a negative binomial distribution with a log link function. The GLMM was implemented in SAS 9.4 with the PROC GLIMMIX and gaussian quadrature estimation. Fixed effects include distance, location, and their interaction with a location by field random effect accounting for field variability. Tukey's adjustment is used to make pairwise comparisons between distances (edge vs. interior) and among sampling points within each location and were reported at the $\alpha = 0.05$ level. Samples from corn did not fit the above model due to very low counts. We, therefore, present raw data from corn using bar charts.

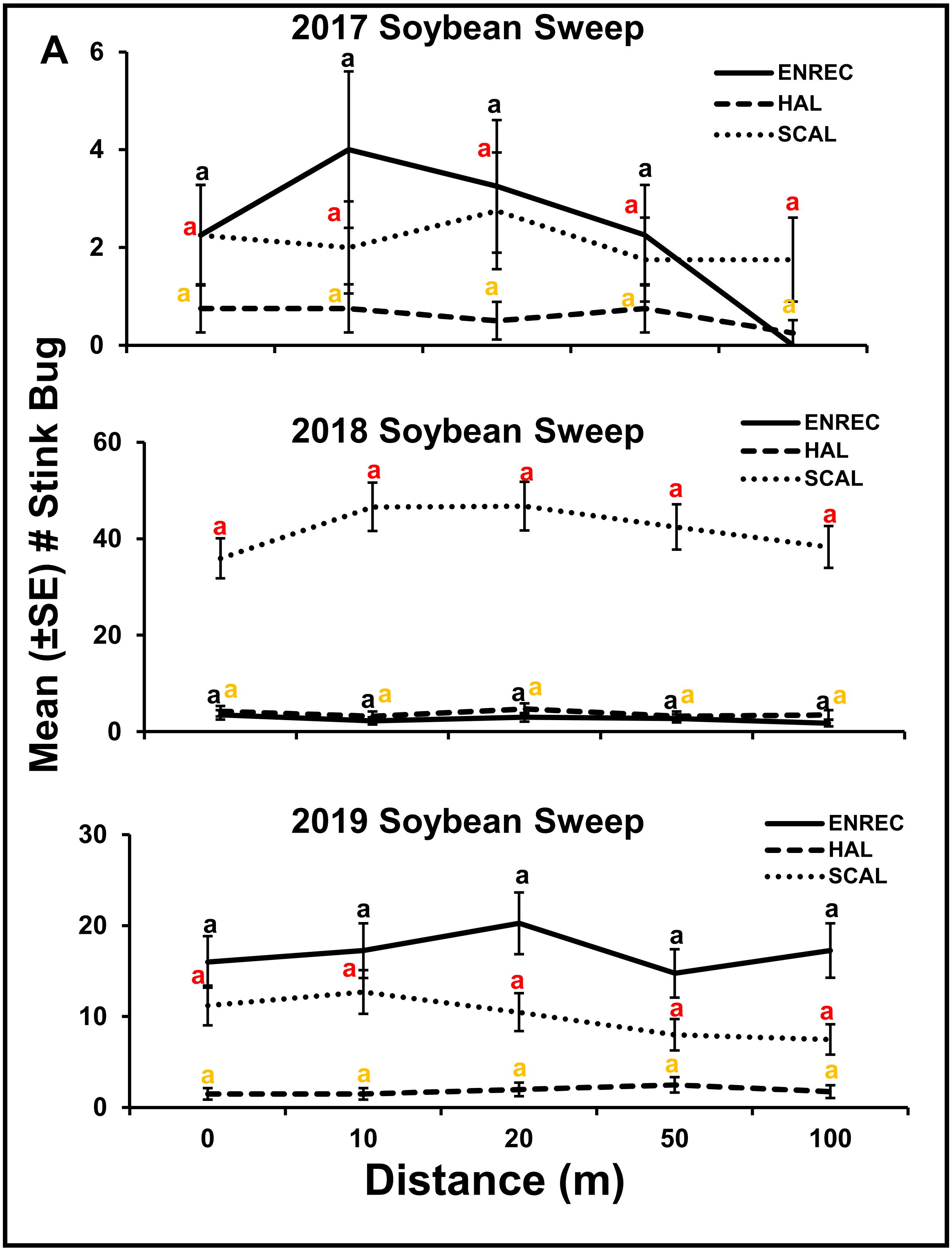
4.4 Results and Discussion

When abundance at field edge and interior were compared, there was no significant different regardless of crop type, year, or location except for transect samples taken from soybean at ENREC in 2017 (t = 2.10, df = 34, p = 0.0436). Our results also showed that there is no significant difference among sampling points when season sum at distances were compared (Figure 4.1. A, B). Our findings differ from the general understanding that stink bug species show edge effect, that is, they are likely to be more concentrated along field borders compared to field interior (Tillman et al. 2009, Reay-Jones et al. 2010, Reeves et al. 2010, Venugopal et al. 2014). Tillman (2009) using *N. viridula* and *E. servus* as model organisms in peanut-cotton interphase linked edge effect with availability of food source in time and space influenced by landscape structure. Similarly, Venugopal (2004) based their findings on edge effect as a result of the influence of adjacent habitats on stink bug densities in corn and soybean fields. These and other similar studies were conducted in the southern region of the United States where the landscape structure and crop diversity greatly differ from the Midwest. Aside a relatively low density, less diversity of surrounding vegetation as well as crop homogeneity in Nebraska landscapes could be a factor responsible for the lack of edge effect. For instance, corn and soybean are the dominant field crops in Nebraska. In contrast, the southeastern region landscape has cotton, peanut, other field crops and perennial trees. Wild hosts and early planted crops play an important role in stink bug development and dispersal, serving as alternative hosts and source of directional infestation. Areas with wooded habitats adjoining crops are prone to more stink bug infestation along the edges (Pannizi 1997). A spatial distribution study carried out in the Midwestern state of Minnesota show that stink bugs aggregate at the border as well as field interior at different levels depending on the species, developmental stage, and field location (Pezzini et al. 2019). This aligns with Nakasuji et al. (1965) where spatial distribution of stink bug was attributed to random invasion to the field by flight and thus, edge effect is not a given.

The highest average count was 4.2 stink bugs per 25 sweeps and 0.6 stink bugs per six plants for soybean in SCAL in 2018 (Table 4.1). This is below the recommended threshold for the Midwest, which is five stink bugs per 25 sweeps or one stink bug per 0.3

m (1 ft) of row for soybean grown for seed production and 10 stink bugs per 25 sweeps or three stink bugs per 0.3 m (1 ft) of row for soybean grown for grain. Stink bug population density in corn was much lower than soybean. Despite the generally low numbers, some locations had a weekly average that exceeded these thresholds when specific sample dates during peak period (July and August) were considered (see Chapter 3, Figure 3.6A-C), as opposed to overall season averages shown in table 4.1. For example, average stink bug number taking from soybean transect at ENREC on August 15, 2017, and August 31, 2018 respectively were 1.13 and 1.0 stink bugs/0.3 m (1 ft) of row. While SCAL had an average of 2.5 and 2.1 stink bugs/ 0.3 m (1 ft) of row on August 22 and 29, 2018. For sweep samples, the weekly average number of stink bug/25 sweeps was 17.25 and 16.6 for SCAL on August 22 and 29, 2018 and 6.75 for ENREC on August 4, 2019. While stink bug diversity and abundance might have increased in Nebraska agroecosystem compared to decades ago, overall population densities in crops are still too low to be of major economic concern.

Figure 4.1. Season sum abundance at each sampling point compared across each location for soybean sweep (A), soybean transect (B).



A
2017 Soybean Sweep
2018 Soybean Sweep
2019 Soybean Sweep
ENREC
HAL
SCAL
Mean (±SE) # Stink Bug
Distance (m)
0
10
20
50
100

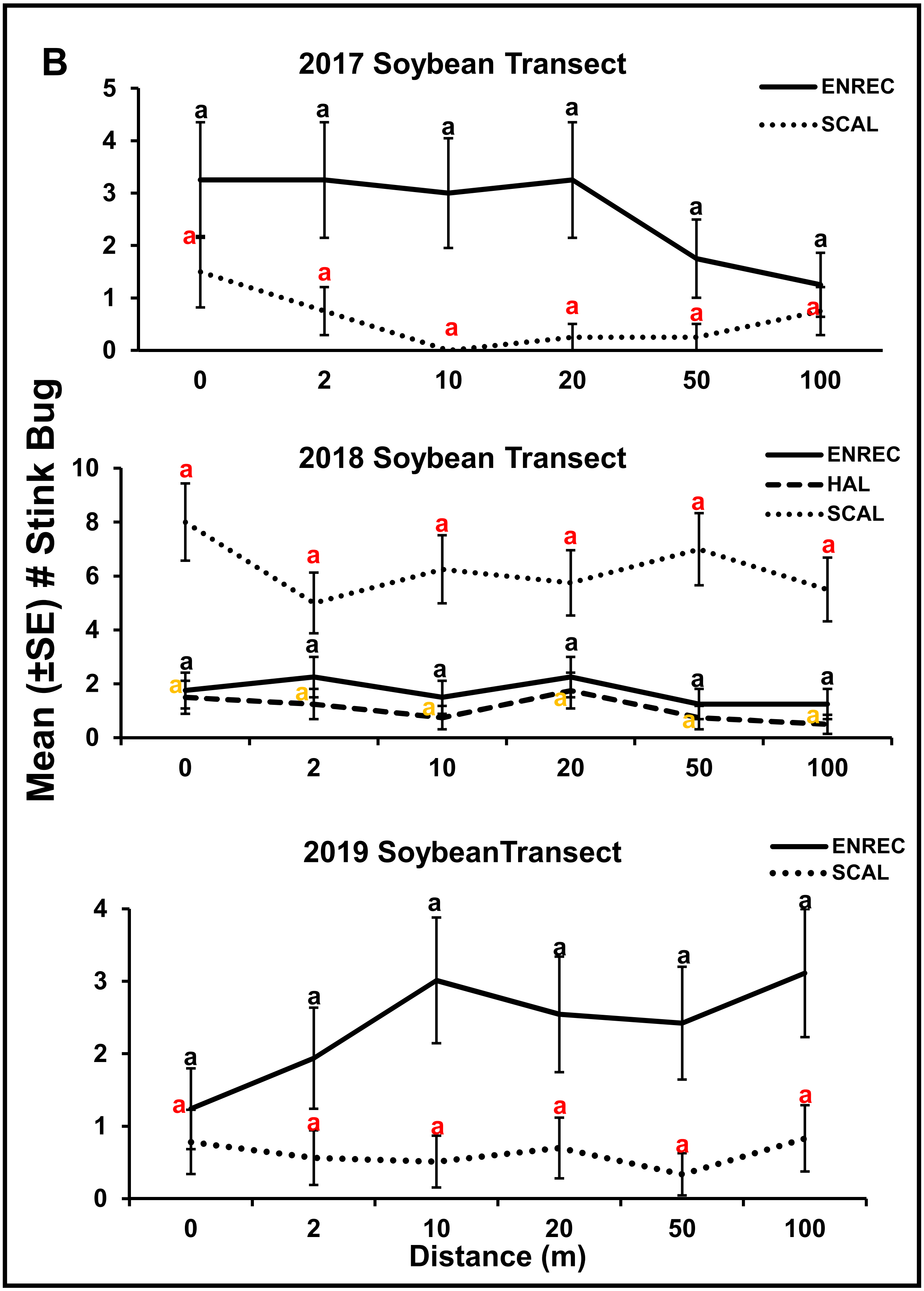

B
2017 Soybean Transect
ENREC
SCAL
2018 Soybean Transect
ENREC
HAL
SCAL
2019 SoybeanTransect
ENREC
SCAL
Mean (±SE) # Stink Bug
0
2
10
20
50
100
Distance (m)

Figure 4.2. Season sum abundance at each sampling point for corn transect.

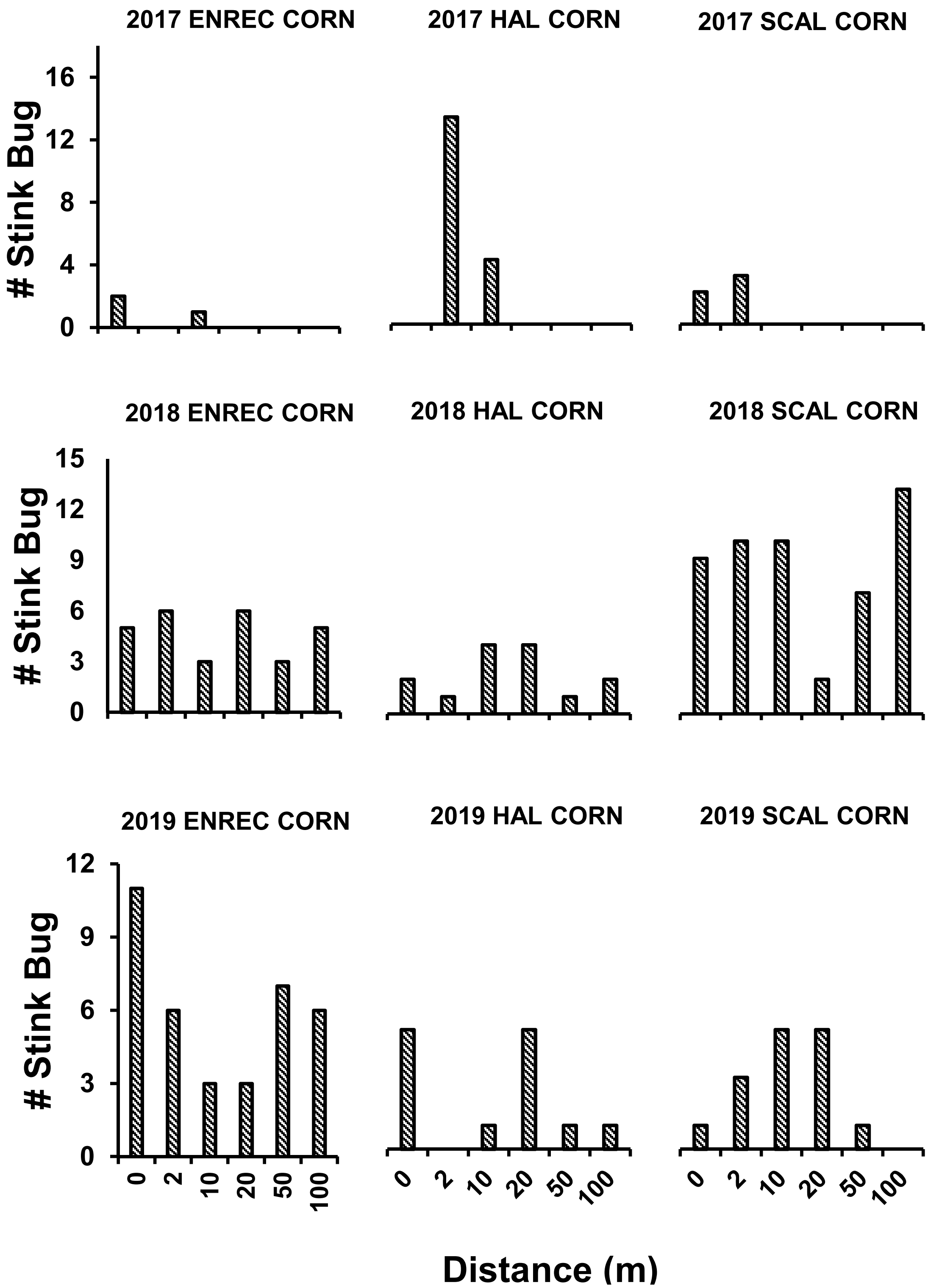


Table 4.1. Season long average number of stink bugs adult and nymph collected per 25 sweeps or transect (1 ft row or 0.3m) for soybean and per six corn plants. (Numbers in parenthesis = samples size)

	Sweep			Transect		
	2017	2018	2019	2017	2018	2019
Soybean						
ENREC	0.4 (120)	0.3 (200)	1.4 (240)	0.5 (144)	0.2 (240)	0.2 (288)
HAL	0.1 (120)	0.4 (180)	0.2 (240)	0.04 (144)	0.1 (216)	0.03 (288)
SCAL	0.35 (120)	4.2 (200)	0.9 (220)	0.1 (144)	0.6 (240)	0.06 (264)
Corn						
ENREC				0.02 (144)	0.12 (240)	0.11 (288)
HAL				0.2 (144)	0.06 (216)	0.05 (288)
SCAL				0.04 (144)	0.2 (240)	0.06 (264)

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CHAPTER 5

PARASITISM OF STINK BUGS (HEMIPTERA: HETEROPTERA: PENTATOMIDAE) BY NATIVE PARASITOIDS IN NEBRASKA

5.1 Abstract

The parasitoid complex infesting stink bugs (Hemiptera: Pentatomidae) in Nebraska was investigated. Three locations across eastern Nebraska were sampled for eggs, nymphs, and adults. In adults and nymphs, parasitism was determined by the presence of Dipteran eggs on the cuticle and/or emergence of puparia. Rearing of puparia that emerged from adult stink bugs confirmed the presence of two tachinid flies: *Euthera* and *Cylindromyia* species. Out of over 3000 adults examined in three years, only 49 individuals were parasitized (~1.5%). Total number of Dipteran eggs recorded was 63, with some individuals carrying multiple eggs. Approximately 60% of egg allocation was on the ventral side of hosts' abdomen, thorax, and limbs. Of the 23 species of stink bug identified from field samples in 2017 - 2019, adult parasitism was observed in only 4: *Euschistus variolarius* (Palisot de Beauvois), *Thyanta custator* Stål, *Chinavia hilaris* (Say) and *Podisus maculiventris* (Say). The most parasitized species was *T. custator*, making up ~57% of total adults parasitized. Nymph parasitism was not observed in this study. To check for the presence of egg parasitoids, feral eggs were randomly collected from the field. Also, sentinel eggs were deployed in soybean fields for 72 hours. Egg masses were placed in a growth chamber [25 ± 1°C, 75 ± 5% RH and 14:10 h (L:D)] and observed for

parasitoid emergence. The species of parasitoid, parasitism and emergence rates were recorded. *Telenomus podisi* Ashmead (Hymenoptera: Platygastridae) was the only parasitoid that emerged from all parasitized eggs. Mean parasitism was ~90% in feral eggs and ~75% in sentinel eggs. Results suggest that parasitoids are a viable option for stink bug control in Nebraska.

5.2 Introduction

Of the 7 insect orders from which parasitoidism evolved, the orders Hymenoptera And Diptera contain members that are natural enemies of stink bugs (Hemiptera: Pentatomidae). These natural enemies, called parasitoids, use different life stages of stink bugs for their development. Egg parasitoids of stink bugs are Hymenopterans belonging to the families Platygastridae (syn = Scelionidae), Encyrtidae and Eupelmidae. Among these, the genera *Telenomus* Haliday and *Trissolcus* Ashmead in the family Platygastridae contain most of all stink bug egg parasitoids (Esselbaugh 1948, Yeargan 1979, Ehler 2002). Other genera of egg parasitoids reported from stink bug include *Anastatus* Motchulsky, *Ooencyrtus* Ashmead, *Gryon* Haliday, and *Hexacladia* Ashmead (Krombein et al. 1979, Krupke and Brunner 2003, Tillman 2011, 2016). Host use by egg parasitoids involve ovipositing in hosts' eggs. The parasitoid develops in the host's egg until adult emergence, causing egg mortality and a direct reduction in pest population before they can cause crop damage (Koppel et al. 2009).

Dipteran parasitoids of stink bugs in the genera *Cylindromyia* Meigen, *Euthera* Loew, *Gymnosoma* Meigen, *Gymnoclytia* Brauer and Bergenstamm, *Hemyda* Robineau-

Desvoidy and *Trichopoda* Bethold, all in the family Tachinidae, lay macrotype eggs on adults and occasionally on nymphs (Aldrich 1988). Tachinid larvae, especially those in the subfamily Phasiinae are obligate ectoparasites and are the second most important natural enemies of Heteroptera (Pentatomidae and Coreidae), after Hymenopteran parasitoids (Stireman III et al. 2006). Adult Tachinids lay eggs on the surface of the host with a few exceptions that lay eggs directly into the hemocoel (Aldrich et al. 1999). In the former, the egg hatches and the larva burrows into the host where it feeds selectively on host's tissues until it reaches the end of the larval stage, after which it emerges from the host's body and pupates on the outside (Askew and Shaw 1986, Stireman III et al. 2016). Adults parasitized by Tachinids continue to feed and reproduce. Consequently, they continue to cause damage to crops until their eventual death after the larva emerges (Harris and Todd 1980).

Approximately 100 species of stink bugs have been reported in the Midwestern United States (Zimmer 1912, Blatchley 1926, McPherson 1982, Rider 2012, Packauskas 2012, Sites et al. 2012, Swanson 2012, Swanson 2013, Koch et al. 2014). The predominant species reported in crops in this region include *Euschistus variolarius*, *E. servus euschistoides, Chinavia hilare, Thyanta custator acerra* and *Podisus maculiventris* (Koch and Pahs 2014, 2015, Koch and Rich 2015, Koch et al. 2014, 2017, Michel et al. 2015). Stink bugs pose an emerging challenge to agricultural production in the Midwest (Michel et al. 2013, Koch and Pahs 2014, 2015, Koch et al. 2017), a region that accounts for more than 70% of all corn and soybean grown in the United States (USDA - NASS 2021). Reduction in the use of broad-spectrum insecticides due to widespread adoption of transgenic crops (Greene et al. 1999, Bundy and McPherson 2000), relative tolerance to pyrethroids, neonicotinoids, and organophosphates in some stink bug species such as *E. servus*, *E. heros* Fab, *C. hilaris* and *Nezara viridula* (L.) (Emfinger et al. 2001, Greene et al. 2001, Sosa-Gómez et al. 2020, Snodgrass 2005, Baur et al. 2010, Temple et al. 2013), and the spread of invasive species (Tindall and Fothergill 2011, Leskey et al. 2012, Michel et al. 2015, Rice et al. 2014) are possible contributing factors to the changes observed in stink bug populations in Nebraska over the last decade (Koch et al. 2014). Several species of parasitoids have been reported on stink bugs (Yeargan 1979, 1982, McPherson et al.1982, Panizzi and Slansky 1985, Takasu and Hirose 1985, McPherson and McPherson 2000, Abram et al. 2014). Some of the egg parasitoids that have been recovered from stink bugs in the United States include *Trissolcus basalis* (Wollaston) (Ehler 2002, Tillman 2016, Abram et al. 2017, Balusu et al. 2019), *Tr. japonicus* (Ashmead) (Rice et al. 2014, Talamas et al. 2015, Herdstrom et al. 2017, Milnes et al. 2017), *Tr. euschisti* (Ashmead) (Yeargan 1979, Krupke and Brunner 2003, Koppel et al. 2009, Tillman 2016), *Tr. edessae* Fouts (Koppel et al. 2009, Tillman 2016), *Tr. cristatus* Johnson (Orr et al. 1986, Tillman 2016), *Trissolcus utahensis* (Ashmead) (Krombein et al. 1979, Krupke and Bruner 2003), *Telenomus podisi* Ashmead (Yeargan 1979, Ehler 2002, Krupke and Brunner 2003, Tillman 2011, 2016), *Oencyrtus californicus* Girault and *O. johnsoni* (Howard) (Ehler 2002). Among the Dipteran parasitoids, we have *Trichopoda pennipes* Fab. (Parish 1934, Aldrich et al. 2006), *Cylindromia fumipennis* (Bigot) (Rings and Brooks 1958, Aldrich et al. 2006, Duncan 2017), *Euthera tentatrix* Loew (Rings and Brooks 1958, Aldrich et al. 2006), and *Gymnosoma filiola* Robineau-Desvoidy (Arnaud 1978, Krupke and Brunner 2003).

The tendency of broad-spectrum insecticides to negatively impact nontarget organisms and trigger secondary pest outbreaks (Panizzi et al. 1977, Nielson et al. 2008, Leskey et al. 2012) is the reason biological control is one of the core components of IPM (Integrated Pest Management). Species such as *T. podisi, Tr. japonicus,* and *Tr. basalis* have previously been evaluated for classical and augmentative biological control of stink bug infestations (Corrêa-Ferreira 1980, Corrêa-Ferreira et al. 2000, Herlihy et al. 2016, Van Lenteren et al. 2018). Identifying the parasitoid complex that occur in Nebraska, the rate of parasitism, field abundance and seasonal phenology is crucial to maximizing the effectiveness of natural enemies as biological control agents, as well as making proper management decisions. This chapter provides a basis for future studies in biological control, conservation and tritrophic interactions relating to stink bug ecology in Nebraska.

5.3 Materials and Methods

Stink Bug Rearing Protocol. Overwintering adults were collected in 2019 and used to raise a laboratory colony for the supply of sentinel eggs. Adults were maintained in a growth chamber set at [27 ± 2°C, 60 ± 5% RH and 14:10 (L: D) h]. Adults were held in transparent plastic containers measuring 50 cm length x 30 cm width x 18 cm height. Rectangular hole measuring 25 x15 cm was cut into each lid and covered with translucent muslin fabric to allow for aeration. Unscented Vaseline was applied along the edge of the rearing containers to prevent stink bug escape. Paper towel was cut to fit the bottom of the rearing container. Two Eppendorf tubes filled with distilled water and threaded with cotton at the tip were placed in each container to maintain humidity. Additional water source was provided with moistened cotton balls placed inside a petri dish. Pure cotton fabric strips 5 x 25 cm were laid at each corner of the rearing container to serve as substrate on which adult females can oviposit. Bean pods, *Phaseolus* sp. were placed inside the container in such a way to facilitate adult contact with them. Grains (peanuts, sunflower, and soybean) were provided in two petri dishes on opposite ends of the container. Food and water, as well as egg removal were performed every 48 to 72 hours to prevent moldiness. To reduce the likelihood of pesticide ingestion, bean pods were treated in the following order: soaked in distilled water for 5 minutes, followed by a solution of sodium bicarbonate (1 tablespoon/1 liter of water) for 40 minutes, distilled water for another 5 minutes, transferred to vinegar solution (1 tablespoon/1 liter of water) for 40 minutes and finally, distilled water for 5 minutes.

Adult Parasitism. Adults and nymphs collected from three locations; ENREC, SCAL and HAL were examined for the presence of Dipteran eggs (Figure 5.1). See chapter 3 for details of field sites and collection methods. Pheromone baited traps were deployed only in 2017. For 2019 samples only, parasitized individuals were separated and kept in an incubator [27 ± 1°C, 75 ± 5% RH and 14:10 (L: D) h] until puparium emergence (Figure 5.2) and parasitoid eclosion. Number of individuals parasitized, number of eggs per specimen, location of egg on host's body, species of stink bug host and associated crop were recorded for each year.

Figure 5.1. Macrotype eggs laid by a Dipteran parasitoid on *Thyanta custator*. Photograph by B. Ademokoya.

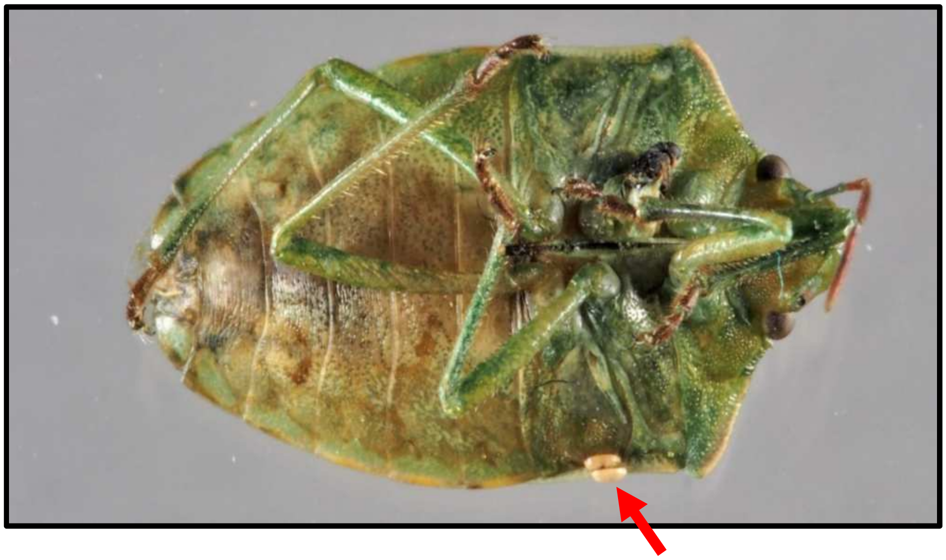
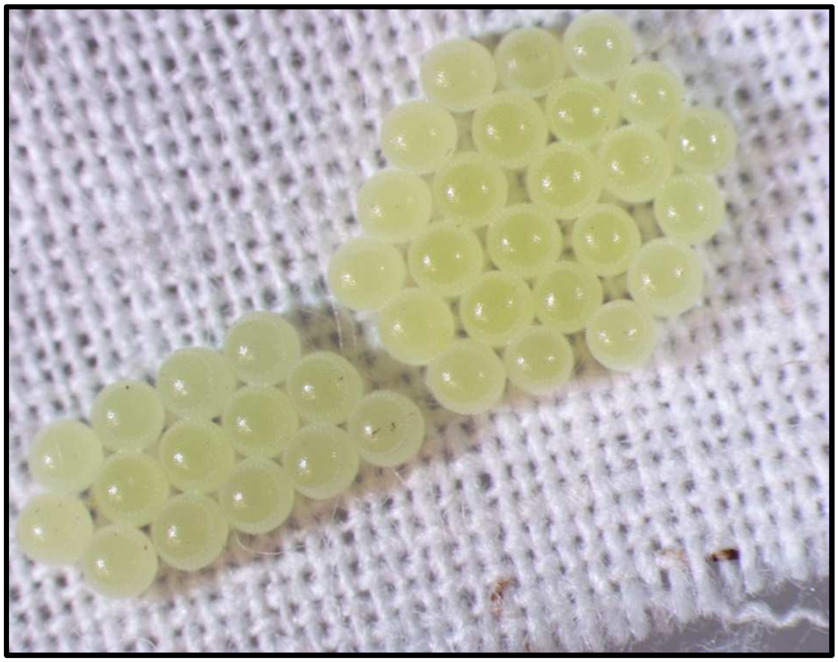


Figure 5.2. Pupal stage of Dipteran parasitoid before adult emergence. Photograph by B. Ademokoya.

Egg Parasitism (Feral and sentinel Eggs). To identify the species of egg parasitoids that occur in Nebraska, stink bug egg masses were randomly collected from transects during summer of 2017 and 2018. These field-collected egg masses were carefully detached from foliage and transported to the laboratory in vented petri dishes. To determine field abundance and parasitism rate, eggs laid by laboratory colony of *E. variolarius*, the most abundant stink bug species in Nebraska (unpublished data), were deployed as sentinel in soybean fields at ENREC and SCAL in late July 2019. Freshly laid eggs, ~48 hours old (Figure 5.3) were cut along with substrate and attached to the underside of a leaf on one of the trifoliate in the upper canopy for 72 hours. For both feral and sentinel eggs, each egg mass was placed in a 2 ml Eppendorf microcentrifuge tube, kept in an incubator [27 ± 1°C, 75 ± 5% RH and 14:10 (L: D) h] and observed for parasitoid emergence. Four holes were made on the cap of each Eppendorf tube with an insect pin to allow for aeration. Parasitoids that emerged were either put in vials containing 95% alcohol or point-mounted for later identification. Eggs where nothing emerged were dissected for dead or immature parasitoids. Sentinel egg masses that either hatched, eaten by predator, or totally missing were voided. Number of parasitized eggs per mass, percent parasitism and emergence, as well as the ratio of male to female (determined by antennal morphology) were recorded. Rate of parasitism was determined by the percentage of eggs that were parasitized relative to the total number of eggs in a mass while rate of emergence was calculated as the percentage of eggs that eclosed relative to the total number of parasitized eggs. Parasitoids upon emergence were provisioned 10% sugar solution in Eppendorf tube threaded with cotton.

Figure 5.3. Less than 2-day old egg masses of *Euschistus variolarius* from laboratory colony. Photograph by B. Ademokoya.



Parasitoid Identification. Parasitoids that emerged were identified using taxonomic keys from published work (Johnson 1984, O'Hara 2012, 2013). For confirmation of identity, some samples were sent to the Systematic Entomology Laboratory at the National Museum of Natural History (Smithsonian Institute, Washington, DC).

5.4 Results and Discussion

Parasitism by Dipteran Parasitoids. Rearing of puparia from parasitized adults happened only in 2019. Emergence confirmed the presence of two subfamilies of Diptera in the family Tachinidae. The Dipterans were identified as *Euthera tentatrix* Loew (Dexiinae) and *Cylindromyia fumipennis* (Bigot) (Phasiinae) (Figure 5.4). Dipteran eggs were observed on the body of adult stink bugs from late May through September (Table 1). Out of over 3000 adults examined, only 49 individuals were parasitized (~1.5%). However, when samples collected from corn and soybean only were considered, parasitism rate was ~4% in 2017, <1% in 2018 and ~2.5% in 2019. Parasitism rates by Tachinid parasitoids are generally low. For instance, Parish (1934) reported a 3.8% parasitization rate by *T. pennipes* on overwintering adults of *E. variolarius*, with even lower rates from two other tachinid parasitoid species. Similarly, Rings and Brooks (1958) reported adult parasitism of *E. variolarius* by tachinids at 4.9% and 1.3% in 1955 and 1956, respectively, in bug collections in Ohio. In Washington state, <2% parasitism was reported for all tachinid parasitoids reared from *Euschistus conspersus* Uhler (Krupke and Brunner 2003). A survey of Dipteran parasitism across nine states in the north central region recorded a mean parasitism rate of 6% (Anderson et al. 2020). In 2019, 17 adults (*E. variolarius* = 9, *T. custator* = 2, *C. hilaris* = 2 and *P. maculiventris* = 4) were observed with macrotype eggs, pupation occurred in 5 and only 3 eclosed. Parasitoids were only reared from *E. variolarius*. Total number of dipteran eggs recorded was 63, with some individuals carrying multiple eggs, up to 4. Single hosts have been shown to carry multiple parasitoid eggs (Todd and Lewis 1976). Incidence of multiple eggs per individuals occurred more (87.5%) in specimens collected from pheromone-baited traps in 2017. This is probably due to limitations in movement caused by the trap as well the attraction of parasitoids to host's pheromone. This kind of attraction has been demonstrated in the field for some Dipteran parasitoids including *Trichopoda pennipes* (Fab.), *Gymnoclytia occidua* (Walker), *E. tentatrix, Gymnosoma par* (Walker) ((Aldrich 1995, Aldrich et al. 2006, 2009, Duncan

2017), *Cylindromyia fumipennis* (Bigot), *Euclatia flava* (Townsend) (Duncan 2017), *Gymnosoma filiola* Loew and *Gymnoclytia occidentalis* Townsend (Krupke and Brunner 2003). Tachinids especially those in the subfamily Phasiinae make use of host pheromone for host detection (Aldrich 1995, Aldrich et al. 2006). Almost 80% of parasitism occurred later in the season from late July to September. The incidence of Dipteran parasitoids laying eggs on nymphs is relatively uncommon (Jones 1988), which explains why no nymph parasitism was observed in this study. Approximately 60% of egg allocation was on the ventral side of hosts' body which include the head, abdomen, thorax, and limbs. Of the 12 species of stink bugs collected from corn and soybean in Nebraska (See chapter 3 for details), adult parasitism was observed in only *Euschistus variolarius*, *Thyanta custator*, *Chinavia hilaris* and *Podisus maculiventris*. Overall, the most parasitized species was *T. custator*, making up ~57% of total. This result varied for 2019 where the most parasitized species was *E. variolarius* (~53%). See Tables 1 A - C for more adult parasitism results. The two species of adult parasitoids recovered from 2019 samples are among the 6 parasitoids reared from stink bugs collected from pheromone-baited traps in Ohio (Duncan 2017).

Figure 5.4. Dipteran parasitoids that emerged from *Euschistus variolarius*. Left: *Euthera tentatrix* (Diptera: Tachinidae: Dexiinae). Right: *Cylindromyia fumipennis* (Diptera: Tachinidae: Phasiinae). Photograpgh by B. Ademokoya.

Table 5.1 A. Adult stink bugs carrying eggs of Dipteran parasitoids (ENREC)

Date	Crop	Stink Bug Species	Egg location	# Eggs/Adult
5/30/2017	Corn [a]	*E. variolarius*	Abdomen	1
6/28/2017	Wheat	*T. custator*	Scutellum	1
7/31/2017	Alfalfa [a]	*T. custator*	Abdomen	1
8/17/2017	Weeds [a]	*T. custator*	Head	1
9/7/2017		*T. custator*	Thorax	3
		T. custator	Thorax	1
		T. custator	Corium	1
		T. custator	Thorax	1
9/19/2017	Corn [a]	*E. variolarius*	Thorax	4
	Alfalfa	*T. custator*	Thorax	1
	Corn	*P. maculiventris*	Head	1

6/7/2018	Blacklight	*C. hilaris*	Thorax	1
6/27/2018		*C. hilaris*	Thorax	1
6/30/2018		*T. custator*	Thorax	1
7/27/2018		*E. variolarius*	Abdomen	1
9/10/2018	Soybean	*T. custator*	Antero-pronotal margin	1
		T. custator	Coxa of fore leg	1
6/19/2019	Soybean	*E. variolarius* [b, c]	Head	1
	Corn	*E. variolarius*	Pronotum	1
7/1/2019	Soybean	*T. custator*	Thorax	1
7/29/2019	Soybean	*E. variolarius*	Humeral angle	1
		P. maculiventris	Eye	1
		E. variolarius	Humeral angle	1
7/30/2019	Corn	*E. variolarius*	Humerus	1
	Soybean	*P. maculiventris*	Humerus	1
	Soybean	*E. variolarius* [b]	Head	1
8/19/2019	Soybean	*P. maculiventris*	Pronotum	1
8/20/2019	Soybean	*C. hilaris*	Corium	1
8/21/2019	Soybean	*C. hilaris*	Thorax	1

Note: [a] Collected from pheromone-baited trap. [b] Pupation occurred. [c] Eclosion occurred. Weeds refer to surrounding vegetations which consists of shrubs and grasses.

Table 5. 1 B. Adult stink bugs carrying eggs of Dipteran parasitoids (HAL)

Date	Crop	Stink Bug Species	Egg location	# Eggs/Adult
7/26/2017	Corn	*E. variolarius* [a]	Thorax	1
	Soybean	*T. custator* [a]	Thorax	1
	Corn	*T. custator* [a]	Thorax	2
8/17/2017	Alfalfa	*T. custator*	Head, thorax	3
9/21/2017	Alfalfa	*T. custator* [a]	Hemelytra, thorax	2
	Alfalfa	*T. custator* [a]	Thorax	1
	Corn	*T. custator* [a]	Thorax, connexivum	3
8/27/2018	Soybean	*E. variolarius*	Abdomen	1
7/2/2019	Soybean	*E. variolarius*	Head	1
7/17/2019	Soybean	*E. variolarius* [b, c]	Pronotum	1
	Soybean	*E. variolarius*	Head	1

Note: [a] Collected from pheromone-baited trap. [b] Pupation occurred. [c] Eclosion occurred. Weeds refer to surrounding vegetations which consists of shrubs and grasses.

Table 5.1 C. Adult stink bugs carrying eggs of Dipteran parasitoids (SCAL)

Date	Crop	Stink Bug Species	Egg location	# Eggs/Adult
8/4/2017	Soybean [a]	*T. custator*	Femur of hind leg	1
8/18/2017	Soybean [a]	*T. custator*	Pronotum	1
8/29/2017	Soybean [a]	*T. custator*	Thorax	2
9/12/2017	Soybean [a]	*T. custator*	Thorax	1
6/13/2018	Wheat	*T. custator*	Coxa of fore leg	1
	Wheat	*T. custator*	Thorax	1
8/13/2018	Soybean	*T. custator*	Thorax	3
	Soybean	*T. custator*	Corium	1
7/19/2019	Corn	*T. custator*	Humeral angle	1

Note: [a] Collected from pheromone-baited trap. [b] Pupation occurred. [c] Eclosion occurred. Weeds refer to surrounding vegetations which consists of shrubs and grasses.

Parasitism by Hymenopteran Parasitoids.

One species of egg parasitoid, *Telenomus podisi* Ashmead (Hymenoptera: Platygastridae) (Figure 5.5), was recovered from both sentinel and feral eggs. Mean parasitism was 89.3 ± 10.7 in feral eggs and 74.9 ± 11.2 in sentinel eggs. Parasitism rate in Hymenopteran parasitoids is typically high and usually exceed 50% in this species (Johnson 1984, Orr et al. 1986, Tillman 2010). Tillman (2010) reported a parasitism rate of 92%, 96% and 98% for *T. podisi* reared from *E. servus, Oebalus pugnax* and *P. maculiventris* respectively. In contrast, a study in Washington state reported a parasitism rate of 0.6% for *T. podisi*, 0.5% for *Trissolcus euschisti* and 2.7% for *Tr. utahensis* (Krupke and Brunner 2013). Among the progeny, a female-biased sex ratio of 3.25F:1M was observed. This is also typical for egg parasitoids of Hemipterans. For example, Balusu et al. (2019) reported a ratio of 4M:1M in *Trissolcus basalis* reared from sentinel eggs of brown marmorated stink bug *Halyomorpha halys* Stål in Alabama. Similarly, a ratio of 2.5F:1M (Ademokoya et al. 2017), 2.4F:M (Hirose et al. 1996) and 3F:1M (Aung et al. 2011, 2012) has been reported from *Ooencyrtus nezarae* Ishii, a generalist egg parasitoid of Heteropterans. Eclosion rate was very low for sentinel eggs (15%) compared with feral eggs (100%). This could be attributed to handling. Egg mases that were either eaten by predators, missing, or hatched at the time of recovery from the field were voided. This accounted for about 40% of all egg masses deployed. Among the egg masses that were parasitized, a higher rate of parasitism was seen in egg masses with lower number of eggs (Table 2B). This trend has been shown by Ehler (2002) and supported by Tillman (2010) who suggested that the rate of parasitization may be inversely proportional to the number of eggs in a mass. Egg parasitoids are the most important group of biological control agents due to their ability to control pest populations prior to plant damage (Koppel et al. 2009).

In conclusion, *Telenomus podisi* is widely distributed in the United States, Canada, and Brazil (Johnson 2013), and it is an important egg parasitoid of several stink bug species including *Nezara viridula, Oebalus pungnax*, *T. custator acerra, C. hilare, Edessa ascra* (syn = bifida) (Say), *E. servus* (Yeargan 1979, Krupke and Brunner 2003, Koppel et al. 2009, Tillman 2010, 2011, 2013). *T. podisi* is a good candidate for augmentative biological control due to its high reproductive rate. Mass rearing and release of *T. podisi* and *Tr. basalis* as biocontrol agents to control stink bugs soybean has been carried out in Brazil

(Corrêa-Ferreira 1980, Corrêa-Ferreira et al. 2000). However, despite the high rate of parasitism, *T. podisi* is a generalist and its effect on nontarget organisms, including predaceous stink bugs, poses a downside to its use as a biological control agent (Torres et al. 1996, Medeiros et al. 1997, Pacheco and Corrêa-Ferreira 2000, Koppel et al. 2009, Margaría et al. 2009, Tillman 2010). Continual adoption of IPM principles through conservation, farmscaping, and judicious use of broad-spectrum insecticides will maximize the potential of the natural enemies identified from Nebraska. Results suggest that parasitoids are a viable option for stink bug control in Nebraska agroecosystems.

Figure 5.5. Parasitized Stink bug egg mass after eclosion of parasitoid, *Telenomus podisi*. Photograph by J. Kalisch

Table 5.2 A. Parasitized Field-collected (Feral) Egg Masses in Soybean fields in HAL.

Date	**# Eggs/Mass**	**% Parasitism**	**% Emergence**
8/10/2017	14	57	100
8/17/2017	13	100	100
8/27/2018	16	100	100
8/27/2018	14	100	100

Table 5.2 B. Parasitism of *E. variolarius* Egg masses placed as sentinel in soybean fields on July 19 and July 29, 2019. Five egg masses were deployed at ENREC and SCAL on each date.

Location	Date	# Eggs/Mass	% Parasitism	% Emergence
ENREC	July 19	12	-	-
		17	0	0
		28	50	0
		6	-	-
		8	0	0
	July 29	8	100	100
		9	100	22.2
		28	85.7	0
		20	-	-
		14	100	0
SCAL	July 19	7	-	-
		14	-	-
		14	100	7

	27	63	17.6
	12	0	0
July 29	18	-	-
	15	-	-
	11	100	36.4
	12	-	-
	9	0	0

(-) represent egg masses that were voided; missing, hatched, or eaten by predators.

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CHAPTER 6

DENSITY-DEPENDENT STINK BUG (HEMOPTERA: HETEROPTERA: PENTATOMIDAE) DAMAGE ASSESSMENT IN CORN

6.1 Abstract

This study evaluated the effect of *Euschistus variolarius* (Palisot de Beauvois) (Hemiptera: Pentatomidae) feeding damage on field corn. Corn ears were artificially infested after pollen shed using zero, one and five stink bugs per corn ear, and maintained till physiological maturity. There is an overall significant effect of stink bug density on the proportion of damaged kernels. Proportion of damaged kernels is 0.22% for uninfested corn ears, 3.14% for corn ears infested with one stink bug and ~18% for corn ears infested with five stink bugs. Pairwise comparison showed that there is significant difference between zero infestation and infestation with 5 stink bugs. Results indicate that kernel damage increases with increasing stink bug density.

6.2 Introduction

The widespread adoption of transgenic crops in the United States and the resultant decrease in the use of broad-spectrum insecticides has caused considerable increase in stink bug (Hemiptera: Pentatomidae) damage in recent years (Greene et al. 1999, Bundy and McPherson 2000). Stink bugs are important pests of field crops in the United States, especially in the southeastern region (Turnipseed and Kogan 1976, Todd and Herzog 1980, McPherson and McPherson 2000, Bryant et al. 2020). However, they are historically not pests of concern in the Midwest until recently when an increase in density was observed (Michel et al. 2013, Koch and Pahs 2014, Koch et al. 2017).

There is very little information on stink bug management for corn growers in Nebraska, unlike other pests of corn such as corn rootworm *Diabrotica* spp. Chevrolat (Pruess et al. 1968, 1974, Darnell et al. 2000, Meinke et al. 1989, Urias-Lopez et al. 2000, Wright et al. 2000, Frank et al. 2015, Wangila et al. 2015, Meinke et al. 2021), corn earworm *Helicoverpa zea* (Boddie) (Siegfried et al. 2000, Peterson et al. 2018), Fall armyworm *Spodoptera frugiperda* (Smith) (Pannuti et al. 2015, Palmer et al. 2019, Montezano et al. 2018, 2019a, 2019b, Da Silva et al. 2021), European corn borer *Ostrinia nubialis* (Hübner) (Siegfried et al. 2001, Zoerb et al. 2003), and western bean cutworm *Striacosta albicosta* (Smith) (Appel et al. 1993, Paula-Moraes et al. 2011, 2013, Hanson et al. 2015, Archibald et al. 2017, Montezano et al. 2017, 2019). This suggest that phytophagous members of the family Pentatomidae are historically not pests of concern in corn production in Nebraska agroecosystems.

Stink bugs feed on corn all season and can cause injury at different growth stages (Annan and Bergman 1988, Apriyanto et al. 1989a, 1989b, Cissel et al. 2015, Babu and Reisig 2018). The seedling stage, VE – V6 (Ritchie 1986), is considered the most vulnerable to stink bug feeding damage due to the possibility of stink bugs feeding on the growing points (Townsend and Sedlacek 1986, Negron and Riley 1987, Annan and Bergman 1988). Feeding injury at seedling stage can result to stunted growth, tillering, vertical holes with yellow edges on leaves, and sometimes, plant death (Townsend and Sedlacek 1986, Annan and Bergman 1988, Bryant et al. 2020). Furthermore, damage to corn ears usually manifests as aborted or deformed kernels, discolored kernels, delayed tasseling and silking, deformed and small-sized ears known as banana ears (Negron and Riley 1987, Annan and Bergman 1988), and predisposition of kernels to pathogens through feeding punctures (Daugherty and Foster 1966, Daugherty 1967). Feeding activities on corn at any period during the developmental stages, either vegetative or reproductive, can eventually lead to yield loss (Negron and Riley 1987, Annan and Bergman 1988, Apriyanto et al. 1989b). Losses due to stink bug damage and control is estimated at millions of dollars every year. For example, annual losses in Georgia corn range from \$2 – 11 million (McPherson and McPherson 2000).

About ninety-one million acres of corn was planted in the United States in 2020. This yielded 14.2 billion bushels with an estimated production value of \$60 million. More than 50% of this come from five Midwestern states; Iowa, Illinois, Nebraska, Minnesota, and Indiana in that order (NASS 2021). Nevertheless, most studies on stink bug damage to corn was conducted in the southeastern region where the predominant stink bug species is different from what is obtainable in the Midwest. The most abundant species in Nebraska is *E. variolarius* which accounts for more than 80% of stink bug samples collected in corn (see chapter 3 for more detail). The purpose of this study is to determine the number of adult *E. variolarius* that will cause considerable damage in corn. Yield loss estimates relative to stink bug density can help to determine Economic Injury Level (EIL) and consequently, provide research-based recommendations for stink bug management to corn growers in Nebraska and by extension, the Midwest.

6.3 Materials and Method

Effect of stink bug feeding on corn was evaluated in summer of 2019 at Eastern Nebraska Research and Extension Center (ENREC) located in Ithaca, Saunders Co., NE. Corn ears between R1(silking) – R2 (blistering) growth stage were artificially infested with adult *E. variolarius* after pollen shed. Field was set up in a Latin square design with three treatments: zero stink bug/corn ear, one stink bug/corn ear and five stink bugs/corn ear. Treatments were replicated three times and each replicate was made up of ten corn ears. The infested corn ears were covered with pollination bags (30 x 50 cm) and secured at the base (Figure 6.1). In addition to preventing stink bug escape, this prevented field-occurring stink bugs and other yield-limiting pests from gaining access to the corn ears. Adult stink bugs used in this study were either first generation laboratory-reared populations or field-collected late instar larvae that were reared to adult in the laboratory. This is to ensure some level of control over the age range of stink bugs used for infestation. Insects were maintained in a growth chamber at 27^{o}C ± 2, 60% ± 5 RH, 14:10 (L:D) photoperiod and fed raw peanuts, unshelled sunflower seeds, green beans *Phaseolus* sp., and water (See Chapter 5 for detailed rearing protocol). Biweekly monitoring was conducted to maintain the same stink bug density by visually examining and counting the number of stink bugs on each covered corn ear. Dead stink bugs were replaced to ensure continuous feeding all through the experimental period which lasted six weeks. At late reproductive stage, corn ears were harvested by hand, labelled appropriately, and brought back to the laboratory. The number of damaged (dimpled/shriveled/aborted), moldy, and normal kernels was recorded. Corn injury was expressed as the proportion of damaged kernels relative to the total number of kernels.

Data was analyzed using a generalized linear mixed model (GLMM) following a binomial distribution with a logit link function. The GLMM was implemented in SAS 9.4 with PROC GLIMMIX. Fixed effects include treatment (stinkbug density) and random effects accounting for the Latin square design (blocked by column, blocked by row/rep) where treatment is applied to the rep and column intersection. Tukey's adjustment is used to make pairwise comparisons between stinkbug density treatments at the α=0.05 level.

6.4 Results and Discussion

Analysis of feeding injury showed an overall significant effect of stink bug density on the proportion of damaged kernels (F = 50.53; df = 2, 2; p = 0.0194). Pairwise comparison showed a significant difference between corn ears infested with zero stink bugs and corn ears infested with 5 stink bugs (t = -10.05; df = 2; p = 0.0178). Estimated percentage of damaged kernels is 0.22 ± SEM 0.09 for uninfested corn ears, 3.14 ± SEM 1.15 for corn ears infested with 1 stink bug and 17.94 ± SEM 5.4 for corn ears infested with 5 stink bugs. Previous studies on corn have linked severity of injury with pest pressure, developmental stage of plant and feeding duration (Clower 1985, Annan and Bergman 1988, Townsend and Sedlacek 1986, Apriyanto et al. 1989, Bryant et al. 2020). Mold build-up was observed around the tip of the corn ear in some of the replicates as well as dark sticky dew on the pollination bag in some replicates. However, these events were independent. Probable causes are aphid infestation or predisposition to pathogens through stink bug feeding punctures. To determine if this had any effect on corn ear injury, the proportion of damaged kernels defined as wrinkled, shriveled, aborted, or punctured were analyzed separately from the proportion of moldy kernels. Results show there was no significant effect of moldiness (F = 0.76; df = 2, 2; p = 0.566). We thus analyzed the proportion of damaged + moldy kernels together (F = 36.52; df = 2, 2; p = 0.0266). Because of these results, subsequent reference to damaged kernels will include data from moldy kernels. In our study, we observed that feeding activities occurred more on the upper first half of corn ears (Figure 6.2). The possible explanation is that the tip is the growing point, which makes it the softest and easiest to access. Babu and Reisig (2018) showed that stink bugs concentrated on different parts of the plant at different growth stage. At the reproductive stage, they reported that 79% of *E. servus* seen on corn plants were found around the primary ear leaf collar. However, they did not specify which part of the corn ear was damaged the most. Damage to corn ear such as primary ear abortion and banana ear deformity was not observed in our study. This is probably because of the growth stage at which infestation occurred (R1- R2). Similarly, infestation with *E. servus* at reproductive growth stage, during tasseling and silk formation reported economic losses in form of kernel abortion and reduced kernel weight but no damage to entire corn ear (Blinka 2008, Ni et al.2010). Studies where deformation and abortion of developing corn ear were reported were infested at vegetative growth stage (Negron and Riley 1987, Annan and Bergman 1988, Bryant et al. 2021).

Stern et al. (1959) proposed the concept of economic threshold (ET) and economic injury level (EIL). These two concepts are essential for translating pest densities and yield loss to dollar values which in turn, is important for making economically justifiable management decisions. In the Midwest, the recommended threshold for corn at the reproductive stage is one stink bug per four plants (25% of plants) during ear development and start of pollen shed, and one stink bug per two plants (50% of plants) from pollen shed to early dough stage (Koch et al. 2017). A similar threshold is recommended for Virginia (Bradley and Bailey 2009), while Georgia recommends treatment at one stink bug/8 plants during V12-VT (ear elongation/ vegetative tassel stage), and 1 stink bug/4 plants at R1 – R2 (silking/pollination to blister) (Buntin 2021). This threshold is lower that what was previously recommended for Georgia (Lee et al. 2007). Depending on end use and management style, Bryant et al. (2020) proposed a much lower threshold of 0.04 - 0.09 bugs/plant for seedling corn and 0.08 – 0.16 bugs/plant for V12/V14-VT. At 9 days of infestation, Ni et al. (2010) proposed an EIL of 0.5 *E. servus* per ear for corn at VT (tasseling) growth stage and less for R1 (silking) growth stage. However, in the same study, feeding injury at R2 (blistering) had no significant effect on kernel damage.

Our study did a damage assessment on corn in reproductive growth stage using varying levels of stink bug infestation to determine the number of stink bug per corn ear that will cause significant damage. While pairwise comparison showed significant difference between zero and 5 stinkbugs (t = -10.05; df = 2; p = 0.0178), proportion for zero vs. one (t = -5.79; df = 2; p = 0.0517), and one vs. five stink bugs were marginal (t = -4.54; df = 2; p = 0.0813) (Figure 6.4). In conclusion, infestation by one stink bug/corn ear over a period of six weeks is enough to cause significant damage in kernels ($t = -9.79$, $df = 2$, $p = 0.0103$).

Figure 6.1. Corn ear covered with pollination bag and secured around the stem. Photograph by B. Ademokoya

Table 6.1. Proportion of stink bug damage to corn ear at various levels of infestation

	Moldy kernels (%)	Damaged kernels (%)	Moldy + damaged kernels (%)
0 stink bug	0.19 ± SEM 0.12	0.22 ± SEM 0.09	0.69 ± SEM 0.24
1 stink bug	0.06 ± SEM 0.05	3.14 ± SEM 1.15	3.38 ± SEM 1.12
5 stink bugs	0.13 ± SEM 0.08	17.94 ± SEM 5.39	18.45 ± SEM 4.99

Figure 6.2. Damage to corn ear at zero infestation (A), 1 stink bug/corn ear (B) and 5 stink bugs/corn ear (C).

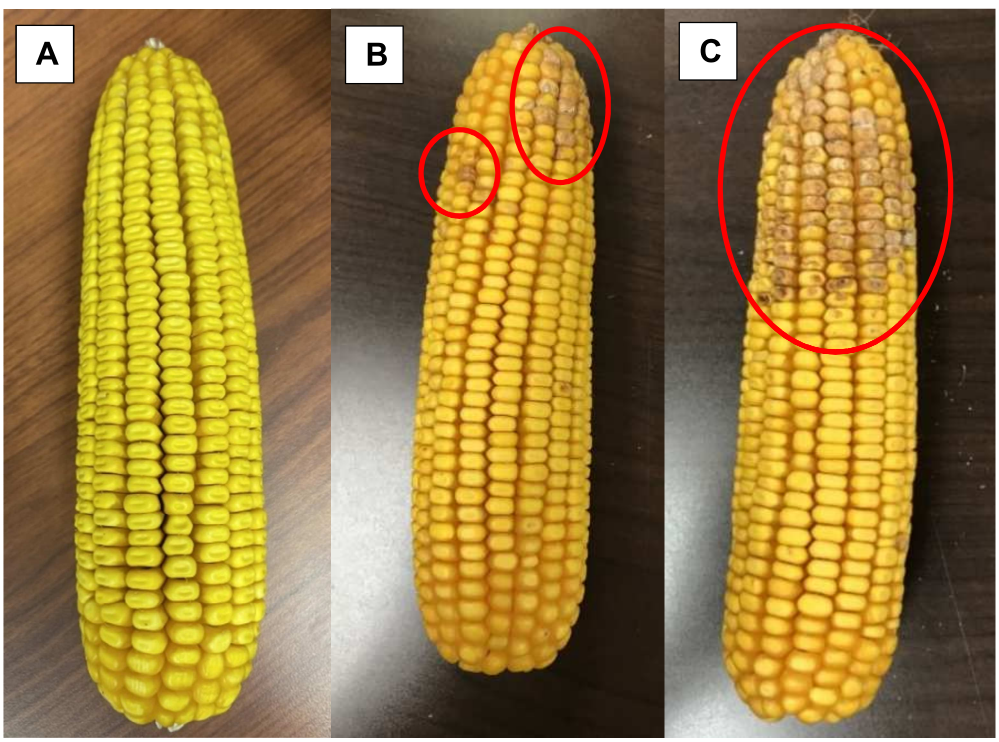


Figure 6.3. Proportion of damaged kernels to normal kernel at different infestation levels.

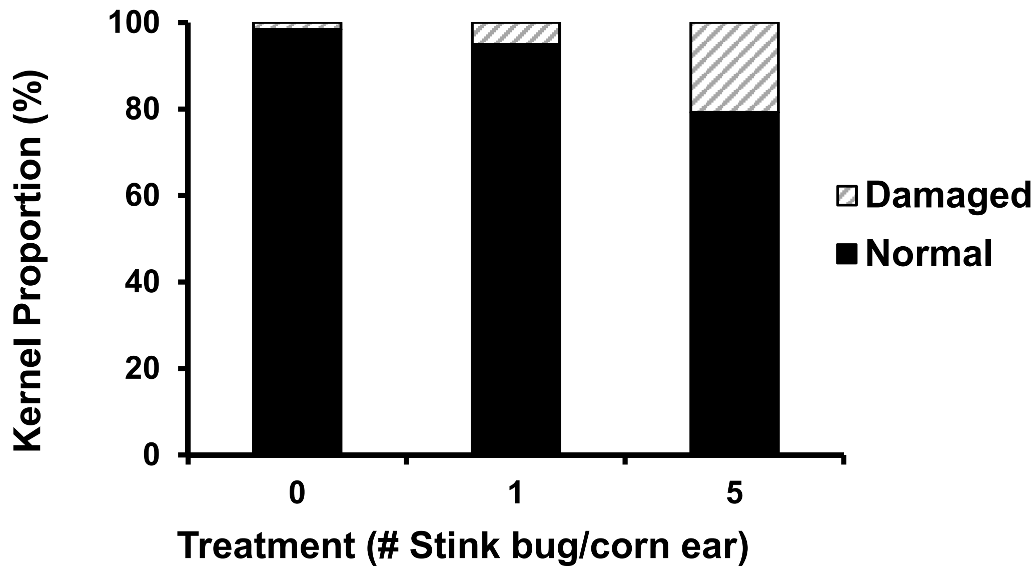
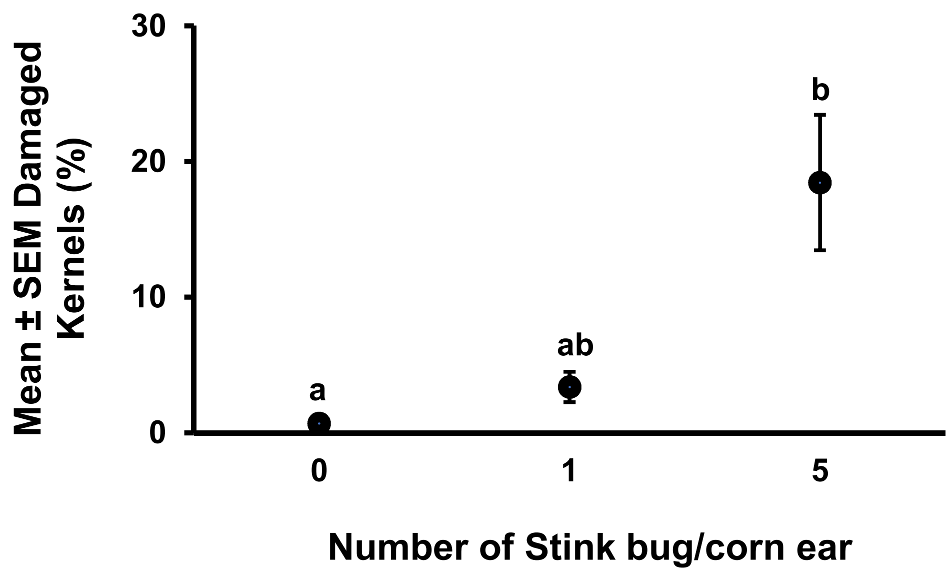


Figure 6.4. Pairwise comparison of kernel damage (α=0.05 level)



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